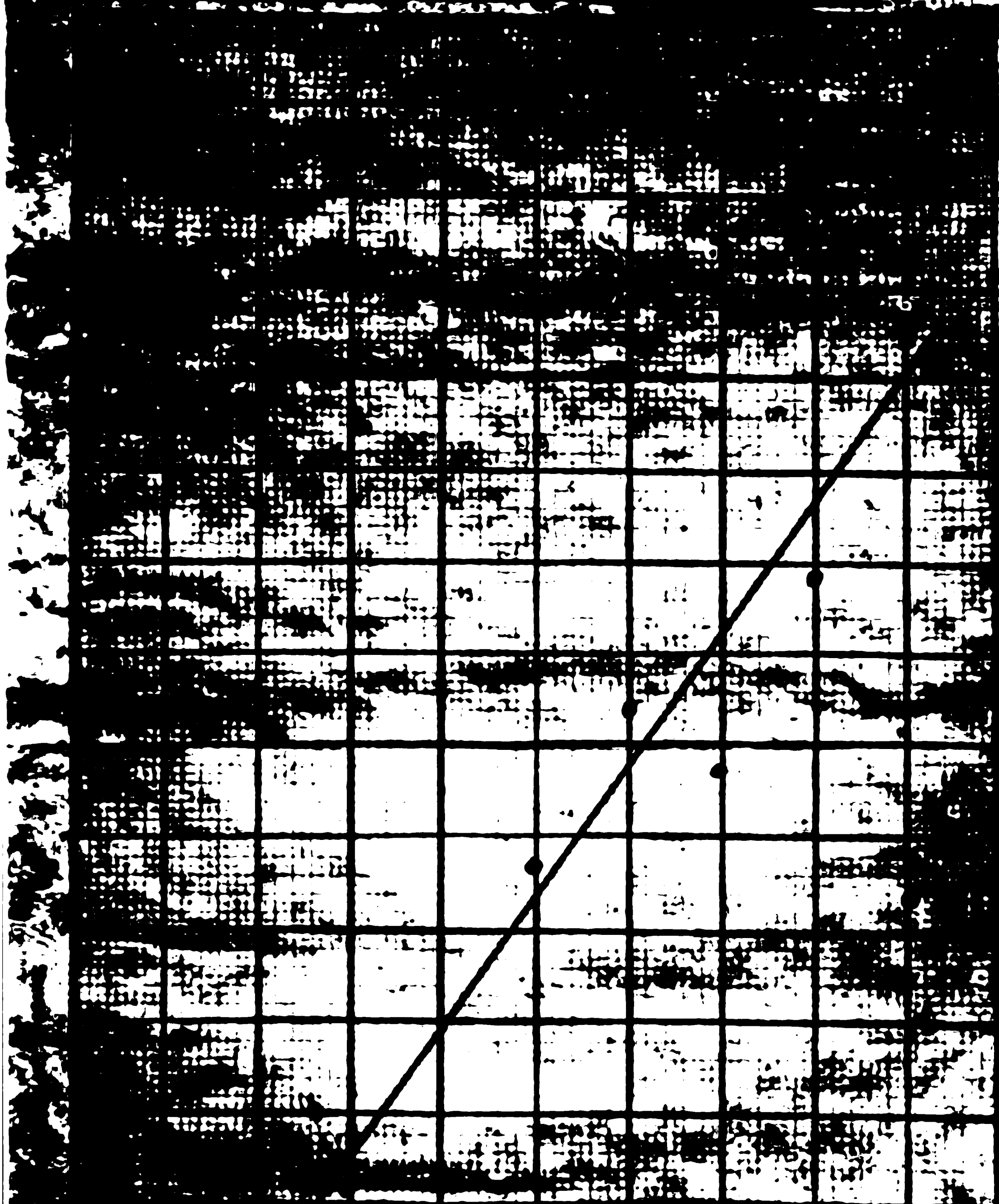

Annual report, Vol. 7, 8, 1910, 11

American Breeder's Association

ANNUAL REPORT

AMERICAN BREEDERS' ASSOCIATION

VOLUMES VII AND VIII

WASHINGTON, D. C.
AMERICAN BREEDERS ASSOCIATION
1912

AMERICAN BREEDERS ASSOCIATION

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Dr. H. J. Webber, Secretary Plant Section.
Prof. H. W. Mumford, Secretary Animal Section.
Dr. Charles B. Davenport, Secretary Eugenics Section.
George W. Knorr, Editorial Secretary.

MEMBERSHIP

Annual, $2.00; Life, $20.00; Delegate, $25.00; Patron, $1,000.

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FOREWORD

The American Breeders Association is rapidly passing beyond the state of need of general discussion to show the relationship and the importance of the work it has assumed to do. Henceforth attention should be directed more specifically to the organization and the financing of research in heredity, to the organization of creative breeding, to the advancement of the general business of breeding pedigreed plants and animals, to the relation of the Association to departments of agriculture and experiment stations, to the accrediting and wide dissemination of varieties of plants and of breeds or families of animals, and also to the further organization of research work in eugenics and in genetics generally.

While either the annual report or the *Magazine* are well worth the price of membership to those who need this kind of information, there are other reasons for inducing breeders for their own interest as well as for altruistic reasons to join this Association. It is fair to state that in ten years every member will be well satisfied that he has the value of his money in his collection of annual reports; that he will feel satisfied with having been of aid in establishing the work of this Association and its publications; that he will consider it an honor to belong to a coöperative organization which is accomplishing such large results. Those who serve as officers, those who regularly attend the annual meetings, and those who freely give their time and labor in investigations and to the preparation of papers have now done sufficient work to justify their asking for general coöperation from the practical plant and animal breeders and from those interested in eugenics throughout the entire North American continent.

It is a matter of some pride that a goodly number of annual and life members have come to the Association almost without solicitation from Europe, Asia, Australia, Africa, and South America. People who look at the work of this Association from a distance, believe it destined to become a movement of great power

The possible constituency of the Association is a very large one as its interests include breeders of pure-bred livestock and plants, seedsmen, horticulturists, physicians, educators, preachers, publicists and

legislators, persons interested in eugenics and in the science of genetics. This constituency should include not only those who have a general interest in this matter from the standpoint of the scientist and the sociologist, but many who are interested commercially. Our milling, our meat-packing and our textile concerns as well as other manufacturing, transportation and merchandising organizations using agricultural raw products are widely and very directly concerned in genetics, and they too should be ready to support the movement of which this organization is the leader.

As many of the papers read or submitted by members at the annual meetings of 1911 and 1912 have been published in the *Magazine* which was established at the beginning of 1911, it was thought advisable to publish volume vii and volume viii together in one cover. The papers have been arranged so that references can be made to either volume as if they had appeared in separate books.

W. M. HAYS,
Secretary.

January 1, 1912.

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SECRETARY'S REPORT

In making a statement the Secretary, W. M. Hays, said: The American Breeders Association has made substantial progress in its seventh year: In memberships, in enhancing general public interest in its work, in the influence it has had in promoting research in heredity and methods of breeding, in promoting the organization of the practical breeding of plants and animals, and in greatly increasing the interest in, and giving direction to, the new movement in eugenics. The Association has also successfully launched a magazine. In 1910, 1132 members paid annual membership dues. There are now 135 life members. This is a gain over the year 1909 of 417 annual members and 26 life members.

The pioneer year of the *Magazine* has had its due share of perplexities and mistakes. The work of collecting material should now be shared more by the three Section Secretaries. These Secretaries should also more actively assist in the organization of the committee work of their respective sections and of sectional programs for the annual meetings. The Association should inaugurate a plan of paid Secretaries. The Secretary recommends that the Association authorize the election of an editorial secretary.

Owing to difficulties growing out of the failure of a bank in which some funds were deposited during the earlier years of the Association, when Prof. Oscar Erf was Treasurer, the auditing of the accounts of the Treasurer has not been made continuous since the beginning. I suggest that the Auditing Committee be directed to audit the accounts of the Association from the beginning of the Association and to report at the next meeting.

I suggest that the Association authorize the placing of the management of the permanent life fund secured from life memberships and other sources in the hands of a reliable trust company for investment.

There is a continuing demand for the annual reports from the beginning; though approximately 50 per cent more reports were published every year than were required to supply the memberships then paid up, the editions were soon exhausted. Institutions, associations, departments and libraries find it impossible to get back numbers. It is suggested that these classes of organizations be allowed to take out perpetual memberships at $25. This is more than life memberships, but these institutions, unlike individuals, live continuously. If this plan is adopted, it is suggested that the Secretary be directed to invite these classes of institutions to become members.

The Committee on Eugenics, organized in 1906 by the Secretary of the Association, W. M. Hays, has made remarkable growth and has done work which is being received favorably by the thinking portion of the people, although occasionally at first the object of levity and satire on the part of the daily press. The vote to change the Committee on Eugenics to a Section on Eugenics coördinate with the Plant Section and Animal Section was taken by mail and was carried by a vote of 995 for to 4 against. A committee, composed of Mr. N. C. Murray, Prof. W. J. Spillman and Dr. T. S. Palmer canvassed the post card vote.

Under that vote President David Starr Jordan became Chairman and Dr. Charles B. Davenport became Secretary of the new section. The activities of this new section are most commendable. Funds for research work have been secured. A Eugenics Record Office has been established at Cold Spring Harbor with Mr. H. H. Laughlin as superintendent and several people are regularly employed in studying human heredity. The first report resulting from this work was one on "Heredity of Feeblemindedness," by Dr. H. H. Goddard, and was published in the third number of the *American Breeders Magazine*, and the importance of this one paper at once served as proof of the wisdom on the part of this Association in inaugurating scientific work in eugenics.

It is suggested that the Acting President of this convention appoint an auditing committee which can examine this report at the office of the Secretary in Washington, and that the report of that Committee be made at once to the Chairman of the Council rather than at the next annual meeting.

A number of the members of the Association have received invitations through Mr. Phillipe de Vilmorin of Paris, to attend the International Genetics Conference which meets in Paris in September, 1911. It is suggested that the American Breeders Associa-

tion invite the International Genetics Conference to meet in North America as its guests in 1913. It is suggested also that the Council be authorized to select delegates to represent the American Breeders Association at the Conference at Paris in 1911.

REPORT OF THE MEETING

The Annual Meeting of the American Breeders Association was held in Columbus, Ohio, on February 4, 5 and 6, 1911, in connection with the National Corn Exposition. The papers, printed in this volume (Annual Report, no. vii) were either read before the Association or were submitted as having been especially prepared for publication in volume vii.

The authorities of the Corn Exposition had very accommodatingly turned over to the Association a room in which to hold its meetings. The Corn Exposition also fitted up, maintained at its own cost, and placed at the disposal of the Association, a lecture hall which was open to the general public. A number of members of the Association had consented to fill the places on a regular daily program of eight lectures, of about half an hour each, discussing in a popular way matters pertaining to their specialty in stock breeding or plant breeding. These popular lectures, many of which were illustrated with lantern slides, were well attended by visitors to the Exposition. It was conservatively estimated that over three thousand persons listened to the lectures, part of the purpose of which was to popularize the work of the Association, to advocate the breeding of better farm plants and animals, and the wider use of farm seeds of high quality. The Association is indebted to the fifteen members who contributed so generously of their time and talent, and whose efforts helped to make this feature of the annual meeting the success it was.

The following motions were submitted by the Council, were acted upon in the business meeting in general session February 3, and passed:

That an editorial secretary be elected.

That the Secretary be authorized to conduct a campaign to extend the membership and to allow commissions on memberships secured and to give special club rates as his judgment may dictate.

That the effort be made to place the management of the permanent fund secured from life memberships and other sources in the hands of a reliable trust company for investment.

That the American Breeders Association invite agricultural colleges, experiment stations, departments of agriculture, societies and institutions inter-

ested in the improvement of plants and animals, and in eugenics, also libraries, to become permanent members of the Association on the payment of $25, such membership to give all privileges of receiving the publications of the Association, and also giving the right to be represented by a delegate in the meetings.

That a committee of three be appointed by the Chair to confer with the Council of the affiliated societies of agricultural science concerning the proposition that the American Breeders Association unite in the affiliation.

That the Association receive the financial report of the Secretary and refer it to the Auditing Committee together with the report of the Treasurer.

That the Auditing Committee be directed to audit all financial reports since the organization of the Association.

That the American Breeders Association invite the International Genetics Conference, meeting in Paris, France, in September, 1911, to meet in the United States in 1913, as the guest of the American Breeders Association.

That the Council be authorized to select delegates to represent the American Breeders Association at the International Genetics Conference in Paris in September, 1911.

That the Committees of the Association may be a Chairman, two committeemen, and that this committee of three be empowered to choose reporters and assistant reporters to carry out the various purposes of the Committee.

Resolutions passed at the Closing Session of the A. B. A.:

WHEREAS, the authorities of the National Corn Exposition have shown every courtesy possible in furnishing rooms, facilities, etc., for this Seventh Annual Meeting of the American Breeders Association, and

WHEREAS, we feel that the meeting has withal been a very successful one, therefore be it

RESOLVED, that the American Breeders Association, in conference assembled, extend to the authorities of the National Corn Exposition its thanks for the generous aid given and the many courtesies shown.

WHEREAS, this Association is yearly placed under greater and greater obligations to its faithful Secretary, Hon. W. M. Hays, for his efficient services and unfailing enthusiasm in supporting and extending the Association, and

WHEREAS, we are keenly alive to the difficulties which he is continually meeting and overcoming in behalf of the Association, therefore be it

RESOLVED, that we extend to Secretary Hays the sincere thanks of the Association for his valuable and disinterested services, and congratulate him on the success and importance of the organization which he has been so instrumental in building up.

WEBBER,
TEN EYCK,
BELL,
Committee.

The following named officers were chosen for 1911:

President, HON. JAMES WILSON, Secretary of Agriculture, Washington, D. C.; Vice-President, DR. WM. SAUNDERS, Director Dominion Experimental Farms, Ottawa, Canada; Secretary and Treasurer, HON. W. M. HAYS, Washington, D. C.; Chairman Animal Section, PROF. W. E. CASTLE, Harvard University, Cambridge, Mass.; Secretary Animal Section, PROF. H. W. MUMFORD, University of Illinois, Urbana, Ill.; Chairman Plant Section, PROF. C. A. ZAVITZ, Ontario Agricultural College, Guelph, Ont., Canada; Secretary Plant Section, DR. H. J. WEBBER, Cornell University, Ithaca, N. Y.; Chairman Eugenics Section, DAVID STARR JORDAN, Stanford University, Calif.; Secretary Eugenics Section, Dr. CHARLES B. DAVENPORT, Cold Spring Harbor, Long Island, N. Y.; Editorial Secretary, MR. GEORGE W. KNORR, Washington, D. C.

The following is the audit of the Secretary's books as reported by the Auditing Committee:

TO THE COUNCIL OF THE AMERICAN BREEDERS ASSOCIATION.

Gentlemen: Your Committee appointed to audit the Secretary's accounts for the periods December 1, 1909, to December 31, 1910, and January 1, 1911, to December 31, 1911, finds that the additions balance and that according to the Secretary's books the accounts are correctly summarized in the financial report of the Secretary.

The Committee finds that all expenditures are supported by receipts except some miscellaneous items, chiefly for postage and express, amounting to $39.94, in 1910, and $3.75 in 1911.

The records show that the Association owns stocks and bonds of par value of $3,100.

H. F. ROBERTS,
H. H. LOVE,
W. W. STOCKBERGER,
Auditing Committee.

Report of the Secretary-Treasurer, 1910:

During the period beginning December 1, 1909, and ending December 31, 1910, the following receipts and disbursements are recorded in the books of the Secretary:

RECEIPTS

Balance on hand from last report		$179.35	
General Fund	$81.35		
Life Dues	98.00		
Annual dues, sale of books, magazines, etc		2,486.48	
Donation from Charles Dickinson		250.00	
Dividends from investments		66.00	
Life dues		561.96	
Total			$3,543.79

EXPENDITURES

For printing, copyrights, etc	$196.56	
Postage	257.73	
Stationery and incidental expenses	54.87	
Traveling expenses	21.08	
Labor and clerical services	400.25	
Surplus annual dues and proceeds from sales of publications transferred to Treasurer N. H. Gentry	1,675.00	
Life dues transmitted to Treasurer N. H. Gentry	480.00	
Balance on hand December 31, 1910, from life dues	179.96	
Balance on hand December 31, 1910, in general fund	278.34	
Total		$3,543.79

PRESENT STATUS OF PLANT-BREEDING INSTRUCTION IN THE UNITED STATES[a]

DR. ARTHUR W. GILBERT

Ithaca, New York

Instruction in plant breeding as a pedagogical unit is very recent, but, like some other new things, it is making very rapid strides. At the present time it is taught in every agricultural college in the United States (Feb., 1911) and in some colleges which are not classified as strictly agricultural. The amount and grade of this instruction, however, are not commensurate with the importance of plant breeding as a philosophical and economic subject.

This survey was undertaken to ascertain how far plant breeding instruction has progressed and if possible pick up a few points from a glance at the whole field which may be of value to instructors. The data are incomplete and inaccurate, first, because not all colleges and departments were heard from and, second, because a misunderstanding of what plant breeding really is still remains. Hence many of the answers are not fully comparable.

The following questions were sent to all of the agricultural colleges in the United States:

In the preparation of the questions below, I have had in mind the following definition of plant breeding: "The principles and practices concerned in the improvement of cultivated plants." This includes a study of variation; selection; hybridization; heredity, including Mendel's Law; cytology; biometry; field methods concerned in plant improvement, and the like.

The questions below refer primarily to undergraduate courses.

1. By what department or departments is plant breeding taught in your institution?
2. Do you have a separate department of plant breeding?
3. What department do you represent?
4. How many hours is plant breeding taught in your department? Answer in total number of weeks and hours per week.
5. How many regular undergraduate students are registered in your courses where plant breeding is taught?
6. About how many strictly plant breeding lectures or recitations do you have in a year?

[a] Paper No. 14, Dept of Plant Breeding, Cornell University, Ithaca, N. Y.

7. How many laboratory periods?
8. What is the general nature of the laboratory work?
9. What instruction do you give to short-term students?
10. How much instruction is given to such students and how many men receive it?
11. Do you have graduate students pursuing plant breeding investigations? How many?
12. For what degrees are they registered?
13. What is the general nature of their thesis problems?
14. Do you use a plant breeding text book? If so, what?
15. What plant breeding bulletins do you use, if any?
16. How much greenhouse space do you have at your disposal for instruction in plant breeding?
17. How much extension work in plant breeding does your department carry on?
18. Will you kindly send clippings from your latest catalogue describing the courses in which plant breeding is taught'?
19. Would it be possible and convenient for you to send examination questions in plant breeding subjects which have been used by you? (If a full response is made to this it might be well to publish a list of questions which would be of assistance to all plant breeding instructors.)
20. How much Mendelism do you teach? What laboratory exercises do you have in this subject?
21. How much biometry do you teach? What laboratory exercises do you have in this subject?

The conditions are so variable at the different agricultural colleges that a direct comparison is impossible. A few deductions, however, can be made.

In regard to the department or departments in which plant breeding is taught, the data seem to be quite complete and interesting. These statistics are based upon the answers received and we are not responsible for omissions.

(a) Horticulture: Vermont, Utah, Connecticut, California, Maryland, New Mexico.
(b) Botany: Alabama, Kansas, New Jersey.
(c) Agriculture: North Dakota.
(d) Agronomy: Washington, Montana, Wyoming.
(e) Agronomy and horticulture: Idaho, Oregon, Minnesota, Ohio, New Hampshire.
(f) Botany and horticulture: Flordia, West Virginia.
(g) Botany and agronomy: Mississippi.
(h) Animal husbandry and horticulture: Tennessee and Pennsylvania.
(i) Farm management and horticulture: Nebraska.
(j) Agronomy, horticulture, and botany: Oklahoma.
(k) Farm crops, horticulture, and botany: Iowa.
(l) Animal husbandary, agronomy, and horticulture: Indiana.

(m) Agronomy, horticulture, botany, and zoology: Missouri.
(n) Thremmatology, agronomy, horticulture, and botany: Illinois.
(o) Plant breeding, horticulture, botany, and farm crops: New York.
(p) Experimental breeding, horticulture, botany, and zoology: Wisconsin.

In cases where plant breeding is reported to be given by the animal husbandry department, the presumption is that the fundamental principles of genetics are taught in such departments and the more technical phases of the subject are taught by the agronomy and horticultural departments. The same is also true of instruction in the department of thremmatology at the University of Illinois.

There seems to be but one State (New York) which has a separate department of plant breeding, where instruction and investigation in this line occupy the entire attention of the staff.

When the number of hours of instruction and the number of students are considered, the amount of plant breeding taught is already extensive.

The number of hours of instruction per year as measured by the number of weeks multiplied by the hours per week, as divided among the different departments, may be grouped and classified as follows:

10–20 hours: Iowa (botany); New York (farm crops).
20–30 hours: Connecticut (horticulture); Kansas (botany); Indiana (agronomy).
30–40 hours: Vermont (horticulture); Illinois (agronomy); Washington (agronomy); Wyoming (agronomy); Missouri (horticulture); Missouri (agronomy); Ohio (agronomy).
40–50 hours: Illinois (horticulture); Minnesota (horticulture); North Dakota (agronomy); Mississippi (agronomy); New York (horticulture); Iowa (horticulture); Florida (horticulture); Oklahoma (horticulture); Wisconsin (horticulture).
50–60 hours: Tennessee (horticulture); Ohio (horticulture); Pennsylvania (horticulture); New Hampshire (horticulture); New Mexico (horticulture); Idaho (agronomy).
60–70 hours: Maryland (horticulture); Montana (agronomy); West Virginia (horticulture).
70–80 hours: Mississippi (botany); Indiana (horticulture); Minnesota (agronomy).
80–90 hours:
90–100 hours: Nebraska (horticulture).
100–120 hours: Alabama (botany).
Over 120 hours: New York (plant breeding); Iowa (farm crops).

There are over a thousand students of collegiate grade pursuing plant breeding studies. This means a large number of young men

trained each year in methods of plant improvement by means of breeding.

One of the most variable factors among the different plant breeding courses is the amount and nature of the laboratory work. Many instructors do not offer any laboratory at all, others make a specialty of this method of teaching. But there is no subject which offers richer material for laboratory instruction than plant breeding. We would suggest that instructors who offer laboratory courses present their methods at the next annual meeting of the American Breeders Association.

Very little plant breeding instruction is being given to short-term students. Some institutions do not have short-course students and in others the period of instruction is so short that other things occupy the entire attention. Teachers who give instruction to such students in plant improvement by breeding have obtained very gratifying results. The young men are filled with enthusiasm and become centers of infection for the carrying on of definite improvement methods with our cultivated plants.

Graduate work seems to be confined to two or three institutions, New York leading with 27 graduate students and Illinois second with 6. Nebraska (horticulture) has 3, Iowa (horticulture) 2, California 2, Missouri (agronomy) 1, Ohio (agronomy) 1, Minnesota (agronomy) 1, New York (horticulture) 1, and Iowa (botany) 1.

Undergraduate instruction is largely dependent upon lectures and assigned readings in plant breeding books and bulletins. Very few instructors use text-books. Davenport, DeVries, Lock and Bailey are commonly used for reference.

Very little extension work in breeding was reported. In some States, however, notably, Illinois, Minnesota, Missouri, California, Wisconsin and New York, where this important line of work is being emphasized, marked success has been obtained. Crop improvement should go hand in hand with soil improvement. Plant breeding offers an excellent field for extension work.

Instruction in the principles of Mendelism and the use of biometry as an aid to the study of variation is notably deficient in plant breeding courses. It is interesting to note that most instructors give many laboratory exercises in the technique of crossing plants but report no instruction in Mendelism which is associated with a definite knowledge of plant hybrids. Exercises in the statistical measurements of variation in plants, platting curves, etc., are interesting and valuable to students.

As instructors get experience in teaching breeding the courses will become better established and more uniform. We believe that a good broad beginning has been made upon which to build for future years.

RECENT PROGRESS IN COTTON BREEDING IN THE UNITED STATES

T. H. KEARNEY

U. S. Department of Agriculture, Washington, D. C.

The cotton crop is one of the most valuable agricultural assets of the United States. The total value to the farmer of the seed and fiber of the crop of 1909 was estimated by the Department of Agriculture at $840,000,000. Production during the past five years (up to 1909) has averaged in round numbers 12,000,000 bales.[a] In 1908 the total crop was estimated at 13,242,216 bales, and that of all other cotton-growing countries at 8,005,528 bales, hence the United States produced 62 per cent of the world's supply of cotton. In 1909, 59.5 per cent of the world's crop was produced in this country. Our exports of fiber in 1908 amounted to about 70 per cent of the crop of that year, in round numbers 9,000,000 bales. In addition to this nearly 50,000,000 gallons of cottonseed oil were exported.

The magnitude of the cotton crop and the fact that it is the main stay of a large section of the United States make this a most important field for the activities of the plant breeder. Nowhere is the need for improvement greater. The practical breeder, any individual farmer in fact, can accomplish valuable results by simple selection for increased yields, larger bolls, etc., while the talents of the trained expert find full scope in developing new varieties adapted to various conditions of environment and to the specialized requirements of different phases of the cotton industry.

Short-staple cotton forms by far the larger part of the total product of the United States, the production of Sea Island and of long-staple Upland varieties being relatively insignificant in point of acreage and total product. Yet the production of long-staple cotton bids fair to increase rapidly in importance, the demand for the staple cottons being far in excess of the visible supply and steadily increasing.

Hence there are two distinct fields for the activity of the cotton

[a] Bull. 107, Cotton Production in 1909. Bur. of the Census.

breeder in the United States, the improvement of the short-staple Upland varieties, which furnish the great bulk of the crop, and the development of long-staple varieties in order to keep pace with the rapidly increasing demand for these cottons.

Short-Staple Cotton Breeding.—Thus far in breeding short-staple cottons the quality of the fiber has received comparatively little attention, the efforts of the breeder having been focused upon increasing the yields and developing large bolls which make picking easier and cheaper. Since a large part of the cotton belt has become infested with the Mexican boll weevil there has been considerable effort made to combat the ravages of this insect by developing early maturing types which permit something of a crop to be made early in the season before the insects have become exceedingly numerous, Other lines of breeding work with short-staple cottons are the development of disease-resistant and drought-resistant types, the first with especial reference to the wilt disease and to boll rot or anthracnose; the second with a view to securing varieties better adapted to the semiarid portions of Texas and Oklahoma into which dry-land cotton culture is steadily pushing.

Long-Staple Cotton Breeding.—There are two principal classes of staple cottons now grown in the United States, (1) Sea Island in the coastal region of South Carolina and Georgia with another area of production in the interior of southern Georgia and northern Florida, and (2) the long-staple Upland varieties known to the cotton trade as Peeler cottons. The center of production of this latter type is the Yazoo Delta in Mississippi, but smaller areas exist in adjacent States. The Department of Agriculture has also been conducting experiments with a view to establishing the culture of Egyptian cotton, of which a considerable quantity is imported every year into the United States for the manufacture of special grades of cotton fabrics, sewing thread, etc. The indications are that this type can be most successfully grown under irrigation in south western Arizona and southeastern California.

In the breeding of long-staple cottons, while increased yields, earliness, and size of bolls are by no means to be neglected, special attention must be paid to quality of the fiber, especially in point of length, strength, and fineness. Breeding improved long-staple varieties is, therefore, a more difficult undertaking and requires the highest skill of the cotton breeder.

The object of the present report is not to attempt a detailed discussion of all lines of cotton-breeding work now in progress in the

United States, but merely to point out some of the more striking results obtained during the past two years in perfecting methods and developing new varieties.

METHODS

Selection vs. Hybridization.—Selection has proven to be the most efficacious means of securing improved types of cotton and much more progress has been made along this line than in hybridization. Numerous experiments have been made in the effort to fix hybrids combining the desirable qualities of two or more varieties, but the general experience has been that progress is very slow and there seem to be few if any well authenticated cases of new varieties originated by this means which have become large factors in cotton production. Numerous breeders have been gratified by the productiveness and the good fiber of their first-generation hybrids only to suffer disillusion when the second-generation plants matured, and after persistent effort to fix the type by selection the work has often been abandoned without reaching any definite results. In this connection it is interesting to quote from a letter from Prof. J. N. Harper, Director of the South Carolina Agricultural Experiment Station.

For a number of years this station has been breeding cotton. This breeding work has been along two distinct lines; one has been the development of new types by carefully selecting the standard varieties; the other has been hybridizing the standard varieties of cotton. We have made considerable progress by the first method. In fact we have come to the conclusion that that is the only method by which we can make permanent improvements in the breeding of cotton. We have made a great number of hybrids, something like four hundred in all, and we find that these hybrids have the tendency of splitting up into any number of different types. I will explain this by stating that we crossed a smooth-seeded cotton with a fuzzy-seeded variety. We obtained a long staple, smooth-seeded variety but every once in a while these black-seeded varieties split up and about half will come fuzzy-seeded. They do not follow Mendel's law, for sometimes they will remain black seeded for two or three years and then some of the stalks will begin to split up.

Mr. C. A. McLendon reports as follows concerning investigations of "Mendelian inheritance in cotton hybrids" which are being conducted by the Georgia State Experiment Station:

Several series of crosses, between Uplands and Uplands, and Uplands and Sea Island, were made in the summer of 1909, and in 1910 a row of thirty-three plants was grown from the seed of each of these forty-two individual crosses. A careful and detailed study has been made of some thirty "unit" characters, including disease resistance, in the case of each of the parent and hybrid plants.

Last season's notes show the correlation, dominance, and intensification of some of the several characters being studied. I might mention that the planting seed from both the parent and hybrid plants have been selfed by the use of small paper bags, and, also, that experiments in connection with this work are being conducted to show the value of "netting" in preventing crossing by bees and other insects and to determine the amount of natural crossing that occurs where greenleaf and redleaf cottons are planted in alternate rows, seed from only the greenleaf plants being used the next season, so that the dominant color (red) of foliage will show in the plants grown from the cross-fecundated seed.

The inheritance of characters in hybrids between different Upland varieties is also being investigated at the Alabama Experiment Station. (See page 18.)

Mutations.—There is considerable evidence accumulating that the work of the cotton breeder is much facilitated when a distinct mutation is selected as the foundation for a new type. Such mutations apparently occur in all types of cotton and are probably more frequent than is generally supposed. Striking examples have occurred in connection with the breeding experiments in Arizona with Egyptian cotton. Two distinct new varieties have been originated there, both of which have been developed from plants so distinct from the Mit Afifi stock, with which the breeding work was begun, as to leave small room for doubt that they were mutations.

One great advantage of varieties thus originated is that decided mutations, differing in marked botanical characters from the parent form, are usually strongly prepotent so that even when ample opportunity for crossing with other types is afforded they come almost true to seed. Thus a four-acre field of the new Yuma variety of Egyptian cotton was grown in Arizona in 1909. This field was planted with seed from the 1908 progeny row of this very distinct type. Although this row was bordered on each side by rows of quite different type, giving exceptionally favorable conditions for crossing, careful examination of all the plants in the 1909 field showed that only about 2½ per cent were markedly different from the general type of the variety

Utilization of First Generation Hybrids.—It has recently been pointed out by Mr. O. F. Cook that one condition under which the crossing of distinct types of cotton may give immediate results of practical importance is the utilization of the "conjugate" or first-generation hybrid plants themselves as the crop. The idea resulted from the observation that plants produced in the first generation after crossing Upland with Sea Island or Egyptian varieties are generally greatly superior to either of the parents in point of productiveness, large size

of bolls, and length and abundance of fiber, as well as in resistance to adverse conditions during the early part of the growing season. In many cases these conjugate hybrids are more alike among themselves than the individual plants of the parent stocks. Mr. Cook suggests that by planting Sea Island or Egyptian in alternate rows with an Upland variety and planting the following year the seed thus produced, a large percentage of the resulting stand will consist of first-generation hybrid plants, since in many localities the flowers of cotton are freely visited by bees and other insects and a great amount of crossing takes place.[b] The hybrid plants are so different from the two parent species that they can readily be recognized in an early stage of their development and all non-hybrid plants can be removed by roguing.

Further experience has indicated that the percentage of hybrids secured by alternate row planting does not always realize the expectation, doubtless partly because of the fact that the blossoming periods of two such different types as Egyptian and short-staple Upland do not coincide. On the other hand, it remains to be determined whether a premium could be obtained for the product that would justify the expense of the skilled labor necessary for producing by hand pollination a sufficient quantity of hybrid seed for commercial planting.

Vegetative Characters of the Cotton Plant.—There has been a strong tendency among cotton breeders to focus their attention chiefly upon the abundance and quality of the lint. Recent experience indicates that the scientific breeder, at any rate, should not neglect the botanical characters of the plants. This has been clearly shown in the investigations carried on by Mr. O. F. Cook and his assistants in connection with the acclimatization of exotic varieties of cotton in the United States. Different types of branching appear to be correlated not only with fruitfulness, but with size of bolls and with quality of the lint. In breeding experiments with Egyptian cotton in the Southwest a study of the stem and foliage characters at a period long before the bolls have opened has been found to greatly facilitate selection of the most desirable individuals and progenies. Such studies have also resulted in perfecting the method of roguing described below.

Local Adjustment of Cotton Varieties.—This term has been coined by Mr. Cook to designate a phenomenon which often appears in

[b] For example, in one progeny row of Egyptian cotton at Yuma, Arizona, grown from seed produced by a plant which occurred in the neighborhood of small plats of Upland varieties, 25 per cent of the total number of plants in the row proved to be first generation hybrids. Allard (*Am. Breeders Mag.*, vol. 1, p. 261, 1910), observed that 20 per cent of the blossoms in cotton fields in northern Georgia were certainly cross pollinated and considers it probable that 40 per cent actually received foreign pollen.

supposedly fixed and uniform varieties when planted in a locality having somewhat different climatic and soil conditions from those of the place of origin. In such cases wide diversity and great departure from the type are often manifested during the first year or two. Growing the variety in the new place for several generations and persistent selection of the most typical individuals will often result in bringing it back to a more uniform expression of the original characters. In this connection Mr. Cook observes:[c]

> The facts of local adjustment go far to explain the apparently capricious behavior of cotton varieties in comparative tests, the same varieties often standing in entirely different relations to each other in different seasons. It becomes evident that the adaptation of a variety to a new place can not be fairly tested in a single season. Not until a new stock has passed through the process of local adjustment and returned to a normal degree of uniformity can the extent of its adaptation to the new place be definitely ascertained.
>
> The facts of local adjustment indicate that our superior varieties may be found adapted to much wider regions than they now occupy. Varieties of real value should have their range extended through local adjustment, instead of being discarded because they fail to show their superiority in the first season. The wider extension of a few superior types of cotton would make it possible to abandon many local varieties and would constitute an important step in the progress of the cotton industry. Greater uniformity in the crop over large areas would increase its commercial value and simplify commercial problems of grading and marketing.

Elimination of Aberrant Forms.—As a result of extensive investigations of stocks of cotton which have produced undesirable variations as a result of transfer to a new environment, or which have become accidentally hybridized with other types, Mr. Cook has discovered that by persistent roguing out of aberrant plants previous to their blossoming it is possible to maintain or restore the uniformity of a variety. Thorough study of the botanical characters of the typical and of the aberrant plants soon qualifies the experimenter to perform this roguing at a very early stage in the development of the plants. All possibility of further crossing between such aberrant plants and the normal ones in the same field is, of course, eliminated by this means.

Lint Index.—A recent publication of the Bureau of Plant Industry[d] calls attention to the fact that the cotton breeder should exercise much discrimination in using the lint percentage as an indication of fertility. Careful weighing of the seed and lint from a number of

[c] Bulletin 159, Bur. Plant Industry, p. 67, 1909.
[d] Cook, O. F. Circ. 11, Bur. Plant Industry, 1908.

different cotton plants showed that the plants with the highest lint percentages were by no means always the ones which yielded the greatest weight of lint, the high percentage being in many cases due to the lightness and small size of the seed. This led to the idea of using as the index of abundance of lint the actual weight of the total quantity of lint from a definite number of seeds, 100 being a convenient number. It is obvious that if selection on the basis of lint percentage results not only in preferring plants with light seeds (and hence in many cases likely to produce progeny of inferior vitality), but also in rejecting plants which actually produce the greatest quantity of lint, this method will have to be abandoned, or, at any rate, used with precaution by the plant breeder as a test of the comparative value of different individuals and progenies.[e] This consideration is, of course, quite apart from the commercial one of using the lint percentage as a means of estimating the actual proportion of lint in a given weight of seed cotton.

Vegetative Propagation.—Recent experiments by the Agricultural Experiment Station in Hawaii, where very encouraging results are being obtained in growing Sea Island, Caravonica, and Egyptian cottons, have shown that a certain means of propagating an especially valuable individual plant without possibility of departure from the type is by the horticultural method of budding. This method, so extensively used by fruit growers and propagators of ornamental plants, has been little applied thus far in connection with field crops. Its adoption opens the way to rapid multiplication of desirable individuals.

Ginning.—Prof. C. L. Newman of the North Carolina Agricultural Experiment Station writes as follows concerning the ginning problem in relation to cotton improvement:

> The greatest obstacle in the way of the development of individual varieties of cotton and of keeping individual strains pure is found in the public gin, and I am convinced that your committee should take this matter up for consideration. Many individual farmers who would at least begin careful selection are deterred from doing so, knowing that their seed when ginned is almost sure to become mixed with other inferior seed. I have obviated this difficulty by the use of a roller-gin for very small lots, such as the production of one stalk, and by the use of a ten-saw gin for larger lots. * * * The installation of a small gin run independently with the public cotton gins would greatly facilitate the breeding or at least a selection of cotton of the individual farmers.

[e] Mr. D. R. Coker reported in this connection that in his breeding experiments he has found no correlation between high per cent of lint and high yield of lint per acre. In fact his highest yielding progenies have usually been of comparatively low lint percentage, ranging from 32 to 34 per cent.

PRINCIPAL RESULTS IN BREEDING DIFFERENT TYPES OF COTTON

Short-Staple Uplands.—Considerable work has been done during the past year or two, both by the Department of Agriculture and by several of the state experiment stations, in breeding short-staple cottons, particularly for increased yield and earliness. The latter factor has been especially important in the western part of the cotton belt where the boll weevil is prevalent. In the South Atlantic States breeding for resistance to anthracnose or boll rot and to the wilt disease has also been given considerable attention.

In South Carolina the state experiment station has originated several promising new varieties. One of these, South Carolina Station No. 18, is a cross between the Floradora and Toole varieties, which has apparently been pretty well fixed. Other improved types have been developed by simple selection from older varieties.

In Alabama Director J. F. Duggar of the state experiment station reports that the breeding work

> Has been devoted to a systematic study of the results of selection for certain qualities and the correlation between certain qualities. The variety most extensively used has been Cook Improved. We have also made some use of Poulnot, Cleveland, and King. Hybridization, especially with reference to the heredity of certain characters, and with a view to developing a variety specially suitable for growth where the boll weevil is present, has received considerable attention. The basis of our work in the plant-to-row method. On the most promising rows several hundred plants are separately ginned each year

In Tennessee and Arkansas Prof. S. M. Bain of the Tennessee Station has worked for several years in coöperation with the Bureau of Plant Industry in developing new types of short-staple cotton, of which the Trice variety appears to be the most promising.

In Texas Mr. D. A. Saunders, of the Bureau of Plant Industry, has made good progress in selecting improved types of the Texas big-boll varieties. The work has been conducted with special reference to securing early varieties adapted to boll-weevil conditions, and early drought-resistant varieties which will permit the extension of cotton culture into the drier portions of Texas and Oklahoma,[f] where the climatic conditions are such as to reduce to a minimum the damage caused by the weevil. In reference to this work the report of the Acting Chief of the Bureau of Plant Industry for 1910 states:

[f] The westward movement of the center of cotton production is an interesting feature in the history of this crop in the United States. By far the greatest recent increase of acreage has taken place in the States of Texas and Oklahoma. During the five years up to and including 1909 45.2 per cent of the total crop was produced west of the Mississippi River. (Bull. 107, Bur. Census.)

Some of the best strains have now reached the stage of commercial production and one of them has been included in the Congressional seed distribution for the present year under the name "Lone Star.' In several tests in the vicinity of Waco, Texas, it has excelled the big-boll varieties now in cultivation, not only in the size of the bolls but in earliness, yield, and length of fiber.

The Bureau of Plant Industry has recently introduced numerous large-boll varieties from southern Mexico and Central America, and as a result of several years' acclimatization and selection some of these types are proving well adapted to the more arid portion of the cotton belt. They seem to be especially satisfactory in regions where irrigation is practiced.

Long Staple Upland Varieties.—In the report of the Acting Chief of the Bureau of Plant Industry for 1910, page 23, the following statement regarding the present status of the Upland long-staple industry appears:

The spread of the boll weevil and the extremely unfavorable climatic conditions of the season of 1909 resulted in a serious decline in the Upland long staple industry of Mississippi and Louisiana. The future of this industry has become a matter of much solicitude, not only to the producers of the long-staple cotton, but to the manufacturers of fine fabrics, who require the superior fiber. Larger quantities of cotton are being imported from Egypt, but the simultaneous decline of production in that country is causing very high prices. Special measures are needed, therefore, to maintain this branch of the cotton industry and to extend it into other districts. Though other parts of the cotton belt may not be able to produce a fiber equal to that of the "Delta" long-staple region, other grades are likely to find a much better market than in former years.

Owing to the high premium commanded by the best of these long-staple varieties they have recently received much attention from cotton breeders. In South Carolina the state experiment station has developed several promising new types, two of which are the results of hybridization and appear to be well fixed. South Carolina Station No. 2 is a cross between the King and the Allen varieties and is described[e] as very uniform in its lint characters. The Black Seeded Blue Ribbon is a hybrid between Allen Long-Staple and Dixon. A third promising new type of long-staple cotton which has given good results at the South Carolina Station has been christened "Tillman's Pride." It is a selection from the Blue Ribbon variety and is said to be distinctly resistant to anthracnose or boll rot.

Mr. D. R. Coker, of Hartsville, S. C., has been engaged in breeding long-staple Upland varieties, with the result that two new types,

[e] Bull. 148, S. C. Agr. Expt. Sta., p. 4.

the Hartsville and the Webber, have been produced. The former was recently tested by the South Carolina Experiment Station with very favorable results. This variety was developed by Mr. Coker from a selection made in a field of short-staple cotton. The Webber variety is a selection from Columbia.

The Columbia variety, developed in South Carolina by Dr. H. J. Webber while in charge of the plant breeding work of the Bureau of Plant Industry, continues to give staisfactory results in the South Atlantic region. It is also becoming decidedly popular in the long-staple area of the Mississippi Valley where the boll weevil has recently appeared, being earlier and more prolific than the varieties formerly grown in that section.

Other new staple varieties are being developed in Texas and Louisiana by Mr. D. A. Saunders, of the Bureau of Plant industry, with special reference to early maturity as a means of producing a crop in the presence of the boll weevil.

In southern and southwestern Texas some of the recently introduced varieties from southern Mexico are being selected under the direction of Dr. O. F. Cook with a view to increasing the length of staple, these types appearing to be peculiarly well adapted to growing under irrigation in the more arid portion of the cotton belt.

There are serious practical difficulties in the way of utilizing the results of plant-breeding work with long-staple cottons, especially in regions where short-staple varieties are generally grown. A scattering distribution of small lots of seed of an improved type has proven wholly ineffectual as a means of bringing about its commercial production. As cotton buying is now organized, it is practically impossible for isolated producers of small lots of long-staple cotton to secure an adequate premium for their crop, if, indeed, they are fortunate enough to receive any premium at all. This subject has received much consideration by Mr. D. R. Coker, who writes as follows:

> I do not believe that an immediate and widespread introduction of any staple cotton variety would be desirable or productive of much good. The Upland staples formerly produced in the eastern section of the belt have earned a very bad reputation with the spinners of staple cotton. This is natural and almost inevitable in any section where the greater proportion of the cotton is of short staple. It almost invariably becomes mixed at the gins with more or less short cotton, and the seed returned to the farmer generally have a small proportion of short-staple seed. The average farmer and average ginner are not sufficiently impressed with the importance of keeping both lint and seed absolutely unmixed. After a few generations of planting under these careless conditions the seed contain a large percentage of short blood, and the staple from these, of course, shows a very high per cent of short fiber.

Mr. Coker adds that in his opinion "It is at present worth while to undertake the establishment of the long-staple Upland industry only in localities where men of intelligence can be induced to coöperate in providing a supply of pure seed and adequate facilities for ginning and marketing the product."

It would appear much easier to establish the culture of an improved variety on a considerable scale by introducing it into a district where cotton growing has not previously been general, or where it is possible to secure concerted action by the entire community of farmers in replacing their inferior varieties with the better seed.

Mr. Coker, as a member of the committee on breeding cotton of the American Breeders Association, has contributed a further statement on this subject, which is here inserted.

" Most of the Upland long-staple cottons produced in the eastern part of the cotton belt have a very bad reputation. This is because the farmers have not been educated in the proper methods of handling this cotton. In territories where an overwhelming majority of short cotton is grown, it is at best very difficult to prevent hybridization, and mixing at the gins. The average farmer in the cotton belt is not sufficiently careful with any of his seed and cotton is the hardest of all seed to keep pure, largely because the gins are not usually cleaned out between bales.

"The National Department of Agriculture, some of the state departments, and a few individuals are now engaged in disseminating the seed of several well-bred and productive varieties of Upland long-staple cotton, but, so far as I can learn, without spreading in advance information that will prepare the farmers and mills to solve the serious problems they will have to encounter before this industry can be successfully launched on a large scale.

"As I have had considerable experience and some success in breeding, planting, handling, and distributing long-staple cotton, I think I am qualified to point out the principal difficulties and some of the ways to avoid them.

"To be successful with staple cotton the farmer must understand the importance of keeping his seed pure and up to standard. He must also have facilities for ginning and a ready market for his product. These, I think, will best be obtained by confining the distribution of long-staple seed for the present to those localities where these facilities can most easily be obtained, starting the work by a thorough campaign of education. Whenever the industry is firmly established in one locality it will spread from this nucleus and the dangers of general distribution will be avoided.

"One of the most serious of these dangers not mentioned above is to the cotton mills. When long-staple seed are distributed in short-staple territory without previous instruction, a good many of the farmers will put up bales containing part long cotton and part short. Such bales are very disastrous to a short-staple mill, frequently causing heavy damage and interference with the work.

"If facilities for ginning and marketing are lacking many of the farmers will abandon the planting of staple cotton as such, but the seed are apt to remain in the country mixed with the short varieties already there and this mixture is very undesirable from the standpoint of the mill.

"The following extracts from a circular which I got out last summer to those who had obtained staple cotton seed from me may be of interest to those who are promoting the planting of staple cotton:

"We are anxious for you to make a success with these (long-staple) seed, and in order to help you do so we offer some suggestions which we think it will pay you to carry out.

"As the difference between the grades of extra staple cotton is much greater than between grades of short cotton, it will be well for you to keep closely up with your picking, allowing none of it to become blue in the field.

"Be sure that no other cotton becomes mixed with your staple cotton.

"See that the gin roll is cleaned out before a bale of this cottom is ginned. If this is not done, other seed will become mixed with your seed and the purity and value of this cotton will soon be lost. Then too, a little short-staple cotton in your bale will injure its sale very much.

"As a great many people in this section have seed of the ("Hartsville") variety, it should be easy for several neighbors to get together and gin their bales one behind the other, thus making it less expensive to the ginner to clean his gins.

" * * * If you have a remnant of ("Hartsville") seed cotton at the end of the season, do not mix with short staple and gin into a bale, but bring this seed cotton here and we will buy it from you. Mills do not want short and long cotton mixed together, and will not buy mixed bales if they know it.

"Never gin any staple cotton that is not perfectly dry, as it will not bring a premium if gin-cut."

Egyptian Cotton.—The United States, although producing 62 per cent of the world's supply of cotton, imports a considerable quantity from Egypt, the imports in 1909 having amounted to 145,000 bales. This cotton is imported from Egypt partly because of the insufficiency of our own supply of long-staple fiber, and partly because the varieties of cotton grown in Egypt possess certain qualities which render them peculiarly useful in manufacturing special grades of thread and fabrics. With this latter fact in mind the Bureau of Plant Industry began

several years ago a series of tests of imported seed of Egyptian varieties at a number of localities in the main cotton belt and also at two or three places in the extreme southwest. For various reasons the results in the southern states were not sufficiently promising to make it advisable to continue the work in that region. The experiments have been continued in the southwest, with the result that several distinct and promising types have been developed from the Mit Afifi seed with which the experiments were begun.

A recent publication[h] describes two distinct new varieties which have originated probably as mutations from the Mit Afifi. These are as different from the parent stock as are the improved varieties which have been developed in Egypt from the same variety and which have in all probability likewise originated as mutations. In addition to these, several selected strains, not distinguishable from the Mit Afifi by their botanical characters, but superior in yield, earliness and quality of the fiber to the plants grown from imported seed, have also been developed. There is good prospect that on the basis of these new varieties and selections Egyptian cotton culture can be successfu ly carried on in southern Arizona and California, although the total area under irrigation that is available in that section amounts to not much more than 500,000 acres. But the high yields which are made possible by the long growing season and by the fact that the water supply is under the control of the farmer make this enterprise a promising one.

Disease Resistance.—The following report on work in breeding for wilt resistance is submitted by Mr. W. A. Orton, of the Bureau of Plant Industry:

This line of work has been in progress since 1899, when it was begun with Sea Island cotton to develop resistance to the wilt disease. After a few years' work, two successful varieties, the Rivers and Centerville, were secured and other strains were developed by the local growers. The department's work was then discontinued and attention centered on the production of wilt-resistant Upland varieties, as it had been learned that the disease was far more widespread and severe on the Upland cotton than on the Sea Island.

The breeding for wilt resistance in Upland cotton, begun in 1900, has resulted in the production of two thoroughly resistant varieties, Dillon and Dixie, which have for several years been distributed from North Carolina to Louisiana but principally in South Carolina, Georgia, and Alabama, where they are now quite widely grown. It

[h] Bull. 200, Bureau of Plant Industry, 1910.

is considered that the problem of cotton wilt has been fully solved by these varieties, as it has been thoroughly demonstrated that whenever proper rotation of crops for the control of root-knot is practiced, or where root-knot does not occur, the resistant varieties are fully satisfactory. In their general qualities they have been brought to as high a standard as the best known varieties of cotton. In several variety tests by experiment stations they have stood at or near the head in production of lint per acre. It is considered that the problem now has become one of education and demonstration. In order to secure the permanent introduction into agriculture of these varieties, local breeders in each district must undertake to produce selected seed. The office is now introducing a coöperative plan to encourage local seed growing.

Excellent work on breeding for resistance has also been done by the Georgia State Board of Entomology, following in the main the lines inaugurated by this department. With the advance of the boll weevil into the eastern states, the situation is changing again, as the existing wilt-resistant varieties appear to be too late for best results under boll-weevil conditions. A new line of breeding was therefore started two years ago, with a view to producing earlier-maturing, large-bolled, wilt-resistant strains by hybridizing between Dillon and Dixie and standard sorts, such as Triumph, Pride of Georgia, Columbia, etc. A portion of these hybrids have been self-fertilized the past two years for the purpose of studying heredity ratios. The second generation grown this season on infected land has given very encouraging results and some hundreds of selections have been made, which will be grown in progeny rows next year.

The following statement regarding the work of the Georgia State Experiment Station in "Continued Selection for Anthracnose Resistance in Upland Cottons," is furnished by Mr. C. A. McLendon of that station.

The first selections in the anthracnose-resistance work were made in fields where the cotton was badly infected with the disease, and several of the so-called varieties that are being planted in this section were chosen for the basal stock for these experiments. The work is continued by growing a large number of plants from each of the selections made each year on land infected with the disease, it being believed from observations made for two winters that the disease passes the winter season in the old plants left in the field. The observations thus far seem to show great resistance in two or three of the varieties being studied, and it is believed that strains practically immune to the disease can be isolated in this way in the course of a few years. And, as mentioned in connection with the hybridization work, anthracnose resistance is also being

noted in the hybrids, thereby making it possible to ascertain the possibility of breeding resistant varieties by this method. In connection with these experiments a study of the relative susceptibility of most of the important varieties of Upland cotton is being made, by making actual counts of the bolls naturally infected and by noting the effect of inoculations artificially made.

Boll Weevil Resistance.—Some of the recently introduced Central American varieties which have originated in the region where the boll weevil is native present a series of adaptations which enable them to meet the attacks of this insect with more or less success. These are described in detail by Mr. O. F. Cook, in Bulletin No. 88 of the Bureau of Plant Industry. Mr. R. L. Bennett, of the Bureau of Plant Industry, devoted several years' work to developing early maturing varieties of Upland cotton with a view to securing types which could mature the bulk of their crop before the development of the latest and largest broods of the insect. Mr. F. L. Lewton, also of the Bureau of Plant Industry, has been making selections from the peculiar variety of cotton grown by the Hopi Indians in the southwest, since this exceptionally early maturing and drought-resistant type is well adapted to escape the ravages of the boll weevil. The work of Mr. D. A. Saunders and of the Alabama Experiment Station in breeding with reference to boll-weevil conditions has already been mentioned (pp. 18 and 20).

LINT INDEX AND LINT PERCENTAGE IN COTTON BREEDING

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It has been the custom of most cotton breeders to use as a criterion for judging productivity, the percentage of lint, i.e., that proportion of the total weight of seed cotton produced by a plant which is represented by the weight of the fiber separated in ginning.

In 1908 Mr. O. F. Cook in a paper entitled "Danger in Judging Cotton Varieties by Lint Percentages," issued as circular No. 11, Bureau of Plant Industry, made it clear that this use of lint percentage must often lead to erroneous conclusions. In plants having small light seeds the proportion by weight of fiber to total seed cotton will be relatively high although the actual quantity of fiber produced by the plant may be lower than the average and vice versa. As Mr. Cook (*ibid.*, p. 5) expresses it—

When the lint percentage is used agriculturally as a basis for estimating the productiveness of a variety the size of the seed must be taken into account, for the same percentage with a large seed means more fiber for the same number of seeds.

As a substitute for lint percentage as a basis for judging productivity, Mr. Cook suggests the use of a "lint index" based upon the weight of fiber borne by a definite number of seeds, 100 being a convenient number. His argument is as follows (*ibid.*, p. 13):

The lint index would give the breeder a far better assurance of superiority than the percentage could ever afford. Reducing the size or weight of the seed would no longer give a variety the misleading advantage that it does by increasing the lint percentage. The chances are fair that the largest amounts of lint will be found on seeds of large size, if not on the largest. At the same time large seeds would not be admitted if the amount of lint were small.

A rather striking illustration of the danger involved in using lint percentage in cotton breeding as a criterion of productiveness recently came to light in the writer's work with Egyptian cotton in the southwest. It was observed during the progress of this work that the lint percentage of the best selections was steadily decreasing from year to year. Thus in a four-acre planting of a very productive variety developed after seven years' of selection from imported seed, the average lint percentage in 1909 was only 27.5, while in Egypt a lint percentage of 33 is commonly obtained. The anxiety caused by this apparently serious decrease in lint percentage was, however, allayed by an observation made by Mr. Argyle McLachlan, who found that in the acclimatized variety the average weight of the seed after removal of the lint was considerably greater than in plants grown from imported seed. The case is thus stated in Bulletin 200, Bureau of Plant Industry, 1910, page 17:

Mr. McLachlan found that imported Mit Afifi seed cotton gave a lint percentage of 33 to 35 and that the delinted seeds weighed only 10 grams per 100. The acclimatized Yuma variety, which gave only 27.5 per cent of lint, had seeds weighing 13 grams per 100. If the seeds had weighed no more than imported Mit Afifi seeds the lint percentage of the Yuma variety would have been 33 (a satisfactory percentage for Egyptian cotton) instead of 27.5. Evidently, therefore, no actual diminution in the quantity of lint on the individual seeds has taken place during the process of acclimatization.

The object of the present paper is to throw further light upon the relations between lint percentage, lint index, and weight of seeds upon the basis of results obtained in experiments with Egyptian cotton in 1910. The observations were made upon two sets of material;

(1) Thirty-eight individual selections in the progeny rows of the Yuma variety of acclimatized Egyptian cotton in the plant-breeding nursery at Sacaton, Ariz.; and (2) seventy-eight samples from a triplicate row variety test of 26 different imported and acclimatized strains and varieties of Egyptian cotton grown at Bard, Cal. In the former case each sample consists of the total product of seed cotton from a single individual plant, while in the latter the conclusions are based upon a representative sample from each row of each variety.[a]

The lint percentage was determined in the ordinary manner by weighing the seed cotton, ginning, weighing the lint after ginning, and dividing the weight of lint by that of seed cotton, the result being checked by weighing also the delinted seed. The average weight of 100 seeds was easily ascertained and from this value the total number of seeds in the sample could be calculated with a probable error of only about 1.0 per cent. The lint index or weight of lint per 100 seeds was calculated by dividing the total weight of ginned fiber in each sample by the estimated total number of seeds and multiplying the quotient by 100.[b]

Table I gives the range, mean, standard deviation and coefficient of variability of lint percentage, lint index and weight of 100 seeds

TABLE 1.—*Summary of observations on acclimated varieties of Egyptian Cotton, with respect to lint percentage, lint index and weight of 100 seeds.*

Character.	Material.	Number of samples.	Range.	Mean.	Standard deviation.	Coefficient of variability.
			Grams.	*Grams.*		
Lint index	Variety Rows	78	3.9 to 5.5	4.80	0.332	0.069
Do	Individual selections	37	3.8 to 5.7	4.65	0.483	0.104
			Per cent.	*Per cent.*		
Lint percentage	Variety rows	78	24.5 to 32.5	28.5	1.870	0.066
Do	Individual selections	37	21.5 to 33.5	26.8	2.180	0.082
			Grams.	*Grams.*		
Weight 100 seeds	Variety rows	78	10.25 to 13.75	12.1	0.837	0.069
Do	Individual selections	38	10.50 to 14.75	12.9	0.859	0.066

[a] The sample consisted in each case of one or two bolls from each plant in the row. Owing to lack of uniformity in the soil of the field where this variety test was located, the difference between the different rows of a single variety or strain was often as great as that between the different strains or varieties. Consequently it was deemed best, for the purpose of the following discussion, to treat each row as a unit rather than to average the results from the three rows of each variety.

[b] On page 14 of the publication above referred to, Mr. Cook suggests a method of calculating the lint index from the weight of 100 seeds and the lint percentage as follows: "The lint percentage affords a means of avoiding this difficulty without lessening the accuracy of the results, for the weight of the

in each of the two sets of material. The coefficient of variability was obtained in the usual manner, by dividing the standard deviation by number of samples.

The customary "correlation tables" were then plotted for each set of material in order to bring out such correlations as might exist between the three pairs of characters, lint index and lint percentage, lint percentage and weight of seeds, and lint index and weight of seeds. The tables showed a pronounced positive correlation in the first pair of characters and an evident though less pronounced negative correlation in the second pair, while, as would be expected, the correlation between lint index (weight of lint per 100 seeds) and weight of the seeds themselves was negligible.

The relations of lint index to lint percentage and of lint percentage to weight of seeds of material from the variety rows and individual selections are given in Table 2.

TABLE 2.—*Coefficients of correlation of lint index with lint percentage and of lint percentage with weight of seed per each lot of material (1) and (2).*

Correlation.	Material.	Number of samples.	Coefficient of correlation.	Probable error.
Lint index × lint percentage.......	Variety rows	78	+0.64	0.045
Do..................................	Individual selections	37[c]	+0.83	0 033
Lint percentage × weight seeds..	Variety rows	78	−0.63	0.46
Do..................................	Individual selections	38	−0.40	0.092

It is evident from these results that a lint percentage above the average is usually associated with a weight of lint per individual seed (lint index) that is also above the average, but the correlation is by no means perfect. As was clearly brought out by the correlation tables from which the coefficients of correlation were calculated, marked exceptions occur. Thus, among the 37 individual selections of the Yuma variety, the highest lint index (5.7) was reached by two plants, one of which gave also by far the highest lint percentage (33.4), while in the other the lint percentage (27.6) was only slightly above the average (26.8) for the 38 plants. On the other hand a plant which

fiber of 100 seeds can easily be calculated after the weight of the seeds and the lint percentage are known. The weight of the hundred seeds divided by the percentage of seed gives the weight of the hundred seeds before ginning. Subtracting the weight of the ginned seeds gives the lint index or weight of the lint of the hundred seeds. With a slide rule it is easier to multiply the weight of the seed by the lint percentage and then divide by the percentage of seed.

[c] In the case of one of the 38 selections there was some uncertainty about the determination of the lint index, hence it was omitted in calculating the corresponding coefficient of corrrelation

gave a relatively high lint percentage (29.4) was considerably below the average in lint index. Of the 78 samples from the triplicate row variety tests the row which gave the highest lint percentage was inferior in lint index to 14 other rows.

As expressed by the coefficients, the negative correlation between the characters lint percentage and weight of seeds is sufficiently pronounced to indicate that a high percentage of lint is in large measure associated with low weight of seeds. This fact, together with that above noted of marked exceptions to the correlation between high lint percentage and high weight of lint per seed (lint index) makes it clear that, as Mr. Cook has pointed out, the cotton breeder who focuses his attention upon lint percentage as a criterion of productivity is likely to throw away some of his best plants, saving those which produce small and light seeds but not necessarily the greatest quantity of fiber.

The positive correlation between lint index and lint percentage is much more pronounced among the individual selections of one variety than among the 26 varieties and strains in the row test, while the negative correlation between high lint percentage and high weight of seeds is much less pronounced in the former case than in the latter. It might be inferred from these facts that lint percentage can be used with greater safety as an index of productiveness in comparing individual plants of a fairly uniform variety than in comparing different varieties. But, as above noted, marked exceptions to the correlation between high weight of lint per seed (lint index) and high percentage of lint occur even among the individuals of the single variety. From the standpoint of the practical plant breeder the exceptions are in this case more important than the rule.

THE RELATION OF CERTAIN EAR CHARACTERS TO YIELD IN CORN[a]

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One of the very important questions arising in the improvement of corn is, To what extent are visible seed-ear characters correlated with yield? Are there certain characters indicative of high yield which should be kept in mind when seed is being selected?

[a] Paper No. 16, Department of Plant-Breeding Cornell University, Ithaca, N. Y.

While experiments have been conducted to determine what characters of the stalk are correlated with yield, no great amount of work, with the exception of that done by Prof. Williams, has been reported wherein the ear characters have been studied in connection with the yields obtained from them. Although the data herein presented are not sufficient to answer this question definitely, they are very suggestive and are given for what value they may have and also to stimulate interest in the matter.

Prof. C. G. Williams,[b] working at the Ohio Station, has published some very interesting results in this line. His results were obtained be selecting out the long and short ears from a variety and testing their yields. He also compared heavy and light ears, tapering and cylindrical ears, rough and smooth dent, and bare with well-filled tips. This work gives some very important results, which are as follows:

He found that the long ears for 22 tests gave 3.97 bushels per acre more than the short ears.

For 18 tests the tapering ears gave a gain of 0.87 bushels per acre over the cylindrical ears, although this gain is not consistent.

The ears with filled tips gave 1.07 bushels per acre more than seed ears with bare tips.

The smooth ears gave slightly more corn per acre than the rough ears.

Heavy seed ears gave 1.93 bushels per acre more than the light-weight seed ears.

The data for this paper are taken from some of the records of the corn-breeding work being conducted by Dr. H. J. Webber at this station. As it is here presented it differs from that of Prof. Williams' in that he is working with greater extremes in the seed ears. It is the plan of this paper to make comparisons with ears which do not differ so markedly in their characteristics as did those used at the Ohio Station. The question discussed here is, To what extent do the different ear characters influence the yield of corn when these characters do not at any time represent the extremes? To make this point more clear, let us illustrate in this manner: A grower picks out a lot of ears for seed which vary in length, weight, number of rows, and other characters. They in no-wise represent the extreme variations, yet is one justified in planting the longer or the heavier ears? For example, is a corn breeder who has several seed ears from the same mother ear to expect higher yields from the longer ear than from the shorter? Will the heavier ear in this case yield the most?

[b] Bulletin 212, Ohio Agricultural Experiment Station.

It is the plan to set forth some data accumulated on this phase of the question. While conducting some corn-breeding plots the past few years there have been collected data on the seed ears and their yields which we are now able to bring together in order to determine what influence certain characters may have on the yield. Such notes as length of ear, the butt and tip circumferences of the ear, weight of ear, weight of cob, number of rows of kernels, together with other notes, have been taken. The seed ears did not represent the extremes of the varieties but only such differences as may be expected between any lot of representative seed ears.

The data are obtained from two varieties of dent corn, namely, Minnesota No. 13 and Funk's Ninety Day, and cover the work of two years. The number of ears used for the Funk's Ninety Day corn was 100 for each year, while in the case of the Minnesota No. 13 there were 77 ears used the first year and 99 the second.

The ears were planted in an ear-to-row plot so that the yield of each ear could be determined separately. At harvesting time the yield was taken in pounds and then the yield per stalk was obtained by dividing the total yield by the number of stalks. The yield per stalk is used in this paper rather than the total yield.

In order to determine the influence of any character on yield the data were arranged in a correlation table in which the character in question was used as subject and the yield per stalk as relative. For example, Table 1 is the correlation between the length of seed ear and yield per stalk for the Funk's Ninety Day variety in 1909. The ear lengths were taken in centimeters and arranged in classes of 1 centi-

TABLE 1.—*Correlation between length of seed ear and yield per stalk for Funk's Ninety Day 1909.*

		Yield per stalk in pounds.										Total
		46 49	49 52	52 55	55 58	58 61	61 64	64 67	67 70	70 73	73 76	
Length of seed ear in cm.	18–19							1				1
	19–20				5	2	1					8
	20–21	1		3	6	4	3	4	1			22
	21–22			2	4	4	9	2	1			22
	22–23		1	2		4	2	6	2			17
	23–24				2	3	3	1	3	1		13
	24–25				3	5	2	2	2	1	1	16
	25–26						1					1
	Totals	1	1	7	20	22	21	16	9	2	1	100

Length of seed ear subject, yield per stalk relative. $r = 0.300 \pm 0.061$.

meter each. The horizontal lines of figures in the table represent the number of seed ears in each class. The yield per stalk is expressed in fractions of a pound and the perpendicular columns of figures represent the number of rows falling in each class. For example, there are 22 rows which give a yield per stalk between 0.58 and 0.61 poùnds.

It will be seen that the ears range from 18.5 to 25.5 centimeters in length, thus offering considerable variation in the type of ear planted. The method of arranging such data in a correlation table is a very good way to express the results found, as it brings before the eye at a glance all of the results. The correlation in this particular case is 0.300 ±0.061.

In Table 2 is shown the relation between weight of ear and yield of Minnesota No. 13 for 1909. The weight of seed ear is here used as subject while the yield per stalk is used as relative. Here the correlation is 0.094±0.076, which shows that the weight of ear in this particular case did not have a very great influence on the yield, although the seed ears range in weight from 270 to 350 grams. This gives a difference of 80 grams, or about 2.8 ounces.

TABLE 2.—*Correlation between weight of seed ear and yield per stalk for Minnesota No. 13, 1909.*

		Yield per stalk in pounds.								Totals
		46 49	49 52	52 55	55 58	58 61	61 64	64 67	67 70	
Weight of seed ear in grams.	260–280	......	......	......	......	1	1	......	......	2
	280–300	......	1	1	5	10	10	2	......	29
	300–320	3	......	......	4	5	5	3	2	22
	320–340	2	1	......	2	4	5	3	3	20
	340–360	......	......	1	......	......	......	2	1	4
	Totals	5	2	2	11	20	21	10	6	77

Weight of seed ear subject, yield per stalk relative. r = 0.094 ± 0.067.

These two tables show how the data were handled. The three characters, length, weight, and number of rows of kernels, were used for the two plots for both years. For the year 1910 the character average weight of kernel was determined for the seed ears. This was obtained by dividing the weight of grain by the total number of kernels. This character was correlated with the yield per stalk for the two plots.

Another character was determined which shows the form of the ear whether tapering or cylindrical. This is expressed in the form of a ratio of tip circumference to butt circumference, or $\frac{\text{Tip circumference.}}{\text{Butt circumference.}}$ By this method it was found that as an ear approaches a cylindrical type the ratio approaches 1. The more tapering the ear the lower the ratio. In this way one is enabled to compare all ratios with yield. Table 3 shows the relation of this ratio to yield in the case of the Funk's Ninety Day Variety.

TABLE 3.—*Correlation between ratio of ear circumference to butt circumference and yield per stalk of Funk's Ninety Day 1910.*

Ratio of tip circumference to butt circumference.	Yield per stalk in pounds. 61–64	64–67	67–70	70–73	73–76	76–79	79–82	82–85	85–88	88–91	Totals
0.79			1								1
0.80											0
0.81									1		1
0.82											0
0.83					1			1		1	3
0.84			1	1			1	2		1	6
0.85	1					1				1	3
0.86		1	1	1	3	2	2	3			13
0.87	1		2	1	2	2		1		1	10
0.88	1			4	2	1	2	4		1	15
0.89			2			2	3	2			9
0.90			2	3	2	1	2	3	1		14
0.91				1	1		1	2			5
0.92			1		1	1	1	1	1	1	7
0.93			2	1	2			3			8
0.94					1	1	1				3
0.95											0
0.96						1					1
0.97								1			1
Totals	3	1	12	12	15	12	13	23	3	6	100

Ratio of ear circumference to butt circumference subject. yield per stalk, relative; $r = 0.014 \pm 0.067$

Here the ratio varies from 0.79 to 0.97, or from an ear where the tip circumference is to the butt circumference approximately as 8 to 10, to an almost cylindrical ear. In this case the correlation coefficient is 0.014 ± 0.067, which shows that for this data there is no difference in yield as obtained by planting tapering and cylindrical ears.

It is not proposed to show all of the correlation tables which have been analyzed in this manner but rather to outline the plan by which the data were handled and to give the results of such calculations.

Table 4 shows the results for the two varieties for 1909 and 1910.

TABLE 4.—*Correlation between ear characters and yield for two varieties of corn for 1909 and 1910.*

Characters correlated.	Minnesota No. 13.		Funk's Ninety Day.	
	1909.	1910.	1909.	1910.
Length of seed ear and yield per stalk..........	−0.099 ± 0.076	0.241 ± 0.064	0.300 ± 0.061	0.058 ± 0.067
Weight of seed ear and yield per stalk..........	0.094 ± 0.076	0.015 ± 0.068	0.323 ± 0.060	0.090 ± 0.067
Number of rows on seed ear and yield per stalk	0.260 ± 0.072	−0.127 ± 0.067	−0.061 ± 0.069	−0.034 ± 0.067
Weight of kernels on seed ear and yield per stalk..	....	0.028 ± 0.068	....	0.043 ± 0.067
Ratio of tip circumference to butt circumference on seed ear and yield per stalk....................	....	−0.162 ± 0.066	....	0.014 ± 0.067
Per cent grain on seed ear and yield per stalk.....	....	−0.177 ± 0.066	....	....

The results here given show that for three out of four cases there is a positive correlation for length of seed ear and yield, while in one case, the Minnesota No. 13 for 1909, there is a negative correlation. For the Funk's Ninety Day 1909 and Minnesota No. 13 1910 there exists a very good correlation. One may say that there is a slight advantage in favor of the long ear.

When we consider the data for weight of seed ear and yield per stalk we find that there is a positive correlation in every case. However, for the Minnesota No. 13 1910 the correlation is so small that it is practically negligible. For the other three tables, however, the correlation is high enough to be significant. From this data there is apparently a small gain in yield due to planting the heavy seed ears.

From the results obtained it is apparent that the number of rows on the ear does not have much influence on the yield. The coefficient of correlation for number of rows on the seed ear and yields for Minnesota No. 13, 1909 was 0.260±0.072, while for the other three tables a negative correlation is found, showing that as the number of rows on the seed ear increases the yield does not tend to increase.

While these data are arranged so as to show the yields per stalk obtained by the seed ears of any particular number of rows, we see that there is no great difference in yield from seed ears of a high or low number of rows of kernels.

Table 5 shows the yields obtained for the Funk's Ninety Day corn for the two years when the ears are grouped according to number of

TABLE 5.—*Yield per stalk obtained from seed ears having different number of rows of kernels. Variety: Funk's Ninety Day.*

Number of rows.	Yield per stalk.	
	1909.	1910.
14	....	0.772
16	0.609	0.786
18	0.612	0.767
20	0.608	0.750
22	0.599	

rows. Certain classes when only one or two ears were tested have been omitted from this table.

This table shows that the yield per stalk obtained from the different seed ears is about the same although the yield is highest for 18-rowed ears in 1909 and 16-rowed ears in 1910. However, this difference is so small that much importance should not be attached to it.

The same data for the Minnesota No. 13 are shown in Table 6.

TABLE 6.—*Yield per stalk obtained from seed ears having different number of rows of kernels. Variety: Minnesota No. 13.*

Number of rows.	Yield per stalk.	
	1909.	1910.
14		0.565
16	0.597	0.551
18	0.592	0.571
20	0.596	0.535
22	0.636	

These data show that there seems to be no definite number of rows which may be associated with high yield.

The correlation coefficients for average weight of kernel on the seed ear and yield per stalk are very small and show that the size of kernel on the seed ear is not associated with yield to any great extent. It is possible that the size of seed has some influence, but in the data given it is evidently overshadowed by other factors. In general we know that larger seed tend to give better plants, other factors being equal.

The relation of the cylindrical or tapering ear to yield is shown by the correlation coefficients of -0.162 ± 0.066, and 0.014 ± 0.067. It will be seen that for one lot of corn there is a negative correlation and for the other a very low positive correlation. This indicates that for

this character there is apparently no constant relation. It would seem that the matter of cylindrical or tapering seed ears would be of very little consequence in selecting seed corn. This is in agreement with the results obtained by Prof. Williams.

TABLE 7.—*Yields per stalk obtained from the shortest and longest, lightest and heaviest ears from the same progeny. Variety: Funk's Ninety Day 1909.*

Progeny No.	Length.				Weight.			
	Short ears.	Yield Per stalk.	Long ears.	Yield per stalk.	Light ears.	Yield per stalk.	Heavy ears.	Yield per stalk.
3-15	21.0	0.593	24.1	0.734	304	0.595	352	0.734
3-27	19.7	0.571	22.2	0.536	284	0.555	318	0.536
3- 9	22.2	0.628	23.5	0.685	295	0.628	347	0.685
3-21	22.2	0.603	26.0	0.616	290	0.576	333	0.603
3-22	18.4	0.656	22.5	0.675	281	0.656	308	0.675
3-31	23.5	0.640	24.8	0.660	313	0.660	367	0.640
3-32	21.0	0.657	24.1	0.709	302	0.724	354	0.637
3-33	21.0	0.579	21.6	0.592	286	0.564	322	0.579
3-34	21.0	0.675	24.4	0.615	279	0.627	349	0.671
3-35	21.6	0.616	24.8	0.568	281	0.616	372	0.578
3-37	19.4	0.561	21.6	0.582	284	0.561	322	0.566
3-40	20.6	0 647	24.1	0.613	295	0.647	342	0.613
3-41	20.6	0.569	24.4	0.594	279	0.622	324	0.594
3-42	....	....	....	....	277	0.527	286	0.632
3-43	19.7	0.603	22.2	0.627	290	0.677	313	0.627
3-46	19.4	0.603	22.2	0.654	299	0.556	354	0.603
3-47	21.3	0.617	23.5	0.651	304	0.617	390	0.668
3-49	22.2	0.622	24.8	0.604	290	0.594	401	0.658
3-50	21.0	0.627	24.8	0.688	286	0.605	363	0.688
3-60	21.3	0.575	24.4	0.583	295	0.583	318	0.647
3-61	21.0	0.572	22.2	0.631	313	0.572	361	0.624
3-64	20.0	0.551	21.6	0.634	263	0.588	342	0.577
3-67	21.0	0.490	22.2	0.578	295	0.490	313	0.641
3-90	21.3	0.529	21.9	0.570	....	....	....	....
3-95	21.6	0.652	24.1	0.629	295	0.629	358	0.652
Average........	20.9	0.601	23.4	0.626	291	0.603	342	0.630

The data were analyzed more closely in order to bring before us the differences obtained between ears which have come from the same mother ear and therefore have the same parentage on the female side. This was done by comparing the yields per stalk obtained from the longest with those from the shortest ear from each progeny and also the heaviest with the lightest.

Tables 7, 8, 9, and 10 show these results in detail for the two varieties for each of the two years. By inspection of these tables it is apparent that the longest or heaviest ears of a progeny do not always give a greater yield per stalk than the shortest or lightest ears. There

are many instances where the smallest ears yielded more per stalk than the largest ears. When the data are all summed, averaged and brought together, as it is in Table 11 we see that in every case there is a slight gain in yield per stalk obtained by planting the longest ears. In some cases this gain is not large enough to be of any significance. However, in 1909 there is a gain of 2.2 per cent for the

TABLE 8.—*Yields per stalk obtained from the shortest and longest, lightest and heaviest ears from the same progeny. Variety: Funk's Ninety Day 1910.*

Progeny No.	Length.				Weight.			
	Short ears.	Yield per stalk.	Long ears.	Yield per stalk.	Light ears.	Yield per stalk.	Heavy ears.	Yield per stalk.
3-60-1	19.6	0.850	20.2	0.628	175	0.628	201	0.850
3-22-2	18.0	0.740	19.2	0.750	184	0.750	211	0.740
3-31-2	20.0	0.612	21.0	0.777	208	0.612	240	0.740
3-43-2	19.0	0.756	21.0	0.888	188	0.756	230	0.760
3-22-3	17.5	0.800	20.0	0.793	177	0.827	221	0.850
3-60-2	17.6	0.700	21.4	0.847	210	0.700	222	0.847
3-46-2	19.0	0.720	20.8	0.702	196	0.720	220	0.833
3-61-2	17.3	0.694	18.5	0.806	180	0.847	188	0.694
3-64-2	17.7	0.850	19.5	0.755	160	0.704	224	0.755
3-15-2	16.6	0.830	19.2	0.830	175	0.771	214	0.830
3-32-3	15.8	0.802	21.4	0.750	170	0.802	225	0.840
3-21-3	18.4	0.900	20.2	0.678	154	0.750	219	0.796
3-43-3	18.9	0.700	19.7	0.745	178	0.700	181	0.745
3-34-3	17.7	0.837	19.4	0.770	169	0.780	183	0.770
3-47-3	17.1	0.663	20.7	0.830	168	0.663	210	0.860
3-50-3	16.9	0.780	21.3	0.830	178	0.880	254	0.867
3-61-3	18.1	0.776	19.0	0.800	172	0.776	190	0.800
3-32-4	18.3	0.680	21.8	0.770	196	0.680	224	0.714
3-34-4	19.6	0.770	20.3	0.710	186	0.770	253	0.710
3-61-4	16.3	0.840	21.8	0.680	163	0.840	302	0.680
3-46-4	19.3	0.750	22.0	0.810	203	0.750	206	0.810
3-49-4	19.2	0.830	20.8	0.762	173	0.714	204	0.810
3-47-5	17.8	0.740	21.4	0.900	164	0.740	203	0.770
3-47-4	16.5	0.784	21.6	0.770	168	0.847	198	0.790
3-64-5	18.6	0.750	21.2	0.724	186	0.724	243	0.750
3-64-7	16.4	0.673	19.8	0.690	161	0.673	189	0.690
Average	18.0	0.763	20.5	0.769	179	0.746	218	0.781

Minnesota No. 13 and 4.2 per cent for the Funk's Ninety Day. This means a gain of 1.1 bushel and 2.1 bushels respectively on a yield of 50 bushels per acre.

The data for weight of ear show that in three out of the four cases there is a gain for the heavy ears. The results for the Minnesota No. 13 for 1910 show no gain for heavy ears while this same variety in 1909 shows a gain of 3.5 per cent or 1.75 bushels on a yield of 50

bushels per acre. The Funk's Ninety Day variety shows a gain of 4.5 per cent in 1909 and 4.75 per cent in 1910, or 2.25 and 2.35 bushels per acre on the basis of a 50-bushel yield.

When the results for the four tests for length of ear are brought together there is an average increase of 1.9 per cent which would mean about 1.4 bushel gain on the basis of the yields reported by Williams. His gain for 22 tests was 3.97 bushels. The results for heavy and

TABLE 9.—*Yields per stalk obtained from the shortest and longest, lightest and heaviest ears from the same progeny. Variety: Minnesota No. 13, 1909.*

Progeny No.	Length.				Weight.			
	Short ears.	Yield per stalk.	Long ears.	Yield per stalk.	Light ears.	Yield per stalk.	Heavy ears.	Yield per stalk.
133-2	20.3	0.623	22.2	0.575	288	0.623	329	0.575
133-3	18.4	0.612	21.6	0.600	277	0.612	281	0.600
133-4	20.3	0.617	21.6	0.588	277	0.588	302	0.617
133-5	17.8	0.635	19.1	0.641	286	0.597	313	0.641
133-7	19.1	0.561	21.0	0.559	286	0.561	306	0.559
133-8	17.1	0.565	21.0	0.601	286	0.586	308	0.601
133-10	19.7	0.574	21.0	0.623	286	0.574	304	0.623
133-13	19.7	0.621	20.3	0.593	311	0.593	318	0.621
1-10-1	18.4	0.646	19.1	0.625	295	0.625	313	0.646
1-11-1	20.3	0.557	21.0	0.470	302	0.557	327	0.470
1-20-1	21.6	0.617	22.9	0.596	306	0.596	327	0.617
1-22-2	19.7	0.609	20.3	0.660	331	0.609	352	0.660
1-23-1	21.0	0.572	21.6	0.675	209	0.572	302	0.675
1-24-1	19.1	0.606	22.2	0.640	297	0.606	313	0.640
1-24-3	19.1	0.606	24.1	0.609	283	0.608	340	0.609
1-26-6	18.4	0.593	21.0	0.631	297	0.631	324	0.593
1-27-1	19.1	0.610	23.5	0.638	302	0.606	340	0.673
1-28-4	17.8	0.550	19.1	0.644	281	0.550	297	0.644
1-32-4	20.0	0.619	22.2	0.663	295	0.619	331	0.663
1-36-1	16.5	0.562	21.0	0.587	297	0.588	333	0.587
Average........	19.2	0.598	21.3	0.611	294	0.595	318	0.616

light ears when brought together show an average increase of 3.4 per cent, or a gain of 2.60 bushels on the basis of the yields reported by Williams. He reported a gain for heavy ears of 1.93 bushels.

These results may be criticised since in comparing the two ears from each progeny we only have known parentage on the mother side. This is true and the author admits it, yet these data are presented more to show what may take place when the regular breeding operations are being followed.

From the results obtained, therefore, it is evident that there will be some deterioration when the smallest ear of a progeny is used

TABLE 10.—*Yields per stalk obtained from the shortest and longest, lightest and heaviest ears from the same progeny. Variety: Minnesota No. 13, 1910.*

Progeny No.	Length.				Weight.			
	Short ears.	Yield per stalk.	Long ears.	Yield per stalk.	Light ears.	Yield per stalk.	Heavy ears.	Yield per Stalk.
1-20-1-2	18.1	0.619	20.2	0.571	218	0.571	226	0.616
1-20-1-1	18.3	0.583	20.2	0.537	227	0.583	238	0.523
1-22-1	17.3	0.641	19.3	0.530	190	0.641	207	0.475
1-23-1	20.8	0.521	21.7	0.643	227	0.643	231	0.521
1-32-1	16.7	0.557	17.3	0.523	185	0.557	226	0.469
1-26-4	17.9	0.515	19.6	0.629	197	0.515	227	0.504
1-27-1-1	18.1	0.648	19.5	0.555	216	0.596	256	0.508
1-27-1-2	17.1	0.535	23.0	0.630	217	0.535	279	0.630
1-27-1-3	19.2	0.594	21.2	0.546	196	0.594	254	0.546
1-27-1-4	18.1	0.643	19.8	0.517	205	0.570	227	0.517
1-28-2	17.8	0.537	19.4	0.504	199	0.542	248	0.501
1-32-3	18.7	0.569	20.5	0.653	219	0.569	253	0.653
1-32-4-1	17.2	0.607	20.0	0.543	201	0.607	253	0.543
1-32-4-2	17.0	0.532	19.9	0.601	185	0.522	233	0.601
1-16-2	17.0	0.579	19.5	0.538	213	0.579	233	0.538
1-34-1	16.6	0.560	20.0	0.600	211	0.612	222	0.580
1-33-1	17.5	0.512	19.5	0.464	218	0.464	243	0.581
1-35-1	16.2	0.435	20.0	0.515	202	0.472	236	0.515
1-36-1	18.2	0.580	21.8	0.622	232	0.484	250	0.580
1-24-1	19.4	0.605	20.4	0.596	214	0.605	254	0.577
1-31-1	18.7	0.572	19.2	0.573	228	0.573	250	0.572
1-46-1	16.7	0.446	20.4	0.598	202	0.446	289	0.621
1-22-2	17.5	0.568	18.0	0.537	224	0.568	228	0.643
Average........	17.8	0.563	20.0	0.566	210	0.558	242	0.557

TABLE 11.—*Average yields per stalk obtained from the shortest and longest, lightest and heaviest ears from the same progeny.*

Variety.	Length.				Weight.			
	Short ears.	Yield per stalk.	Long ears.	Yield per stalk.	Light ears.	Yield per stalk.	Heavy ears.	Yield per stalk.
Funk's 90 Day 1909...............	20.9	0.601	23.4	0.626	291	0.603	342	0.630
Funk's 90 Day 1910...............	18.0	0.763	20.5	0.769	179	0.746	218	0.781
Minnesota No. 13 1909............	19.2	0.598	21.3	0.611	294	0.595	318	0.616
Minnesota No. 13 1910............	17.8	0.563	20.0	0 566	210	0.558	242	0.557
Average...............	19.0	0.631	21.3	0.643	244	0.625	280	0.646

rather than the largest. Then if these short ears reproduce short ears as well as low yield, there would be a gradual loss in yield if this practice were to be continued many years.

From the data at hand, then, there is evidently some effect of size of ear both in respect to length and weight on the yield of the off-

spring. On the other hand, such characters as number of rows, average weight or kernel, and ratio of tip to butt do not have any very marked effect on yield.

It is interesting in this connection to note what Pearl[c] says on this point while working with sweet corn. Although the complete data are not as yet reported, he concludes from his preliminary work that "Two years' ear-to-row tests furnish no evidence that there is any close association or correlation between the size or conformation of the seed ear and the *yield* of corn obtained from it upon planting. The large, well tipped, and beautifully shaped ear is as likely as not to prove a poor yielder when planted. This result means that the external, visible characters of the ear are a very unreliable indication of its probable worth for seed purposes * * * ."

It is possible that differences may exist between different varieties in regard to these points. This question is an important one and should receive consideration in the planning of corn experiments. In fact, any information obtained in regard to characters which may be associated with yield is of the greatest importance.

THE HEREDITARY CHARACTER OF THE NUMBER OF ROWS IN EARS OF CORN

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Some data bearing on the question of the hereditary character of the number of rows in ears of corn is herewith presented, not with the idea of conclusively settling the matter but as throwing some light upon it which may prove of interest to other workers along the same line.

The data were not secured from an experiment conducted specially for the purpose, but were compiled from results obtained in the breeding and selection work incident to carrying on the ear-row test of corn. The variety used was a strain of Minnesota 13, a yellow dent. The ears produced in 50 hills from each of 49 parent ears were inspected as to the number of rows, a total of 7044 being counted.

Of the 49 parent ears, 5 had 14 rows, 24 had 16 rows, 16 had 18 rows, 3 had 20 rows, and 1 had 22 rows. All of the ears produced were counted, nubbins as large ears, the count being made one-third the distance from the butt to the tip.

[c] Bulletin 183, Maine Agricultural Experiment Station.

The following tabulation will indicate the number of rows on the parent ear, the number of ears secured from 50 hills of each parent, and the percentage number of ears of offspring with 10 to 24 rows.

Parent ear.	Number of rows.	Percentage Number of ears of offspring with								Total Number of ears.
		10 rows.	12 rows.	14 rows.	16 rows.	18 rows.	20 rows.	22 rows.	24 rows.	
1	16		22 0	46.2	16.6	11.7	3.4			145
2	16		7.2	18.8	39.1	25.3	8.0	1.5		138
3	16		12.6	28.0	36.3	18.8	4.2			143
4	14	0.6	9.2	29.4	34.1	22.7	2.7	1.3		150
5	18		6.0	25.3	35.3	26.0	6.6	0.6		150
6	14		28.7	37.6	35.6	2.0				101
7	16		3 5	22.2	40.3	21.5	9.0	1.4	2.0	144
8	18	0.6	13.9	25.2	35.9	18.2	3.7	2.5	0.6	159
9	18		10.9	29.2	42.3	13.9	3.6			137
10	20		2.1	9.8	30.0	34.3	18.8	4.9		143
11	20		16.0	30.0	25.7	13.2	13.2	2.0		144
12	20		12.3	25.3	36.5	15.4	9.9	0.6		162
13	16		10.7	42.8	35.9	9.3	1.2			159
14	16	3.0	15.0	45.8	24.1	10.8	1.2			166
15	22			8.5	21.3	34.2	17.8	13.4	4.8	164
16	16		10.7	25.3	34.7	23.3	4.6	1.3		150
17	16		11.0	31.7	37.9	15.9	2.0	1.4		145
18	16		2.0	15.4	33.6	26.8	14.8	6.7	0.7	149
19	14	0.7	16.8	30.0	34.3	16.8	0.7	0.7		137
20	16		3.0	15.0	39.1	25.6	14.3	1.5	1.5	133
21	16		7.8	14.9	39.0	21.3	14.2	1.4	1.4	141
22	16		4.3	22.1	40.7	27.1	3.5	2.2		140
23	14	2.7	25.2	34.7	27.2	8.2	0.7	1.3		147
24	16		6.4	24.8	40.4	22.0	5.6	0.7		141
25	18		8.8	23.0	33.8	23.6	8.1	2.7		148
26	18		2.0	13.7	35.6	26.7	14.4	6.2	1.4	146
27	18		8.7	22.6	32.8	20.5	12.4	2.2	0.7	137
28	16	0.9	11.0	38.5	29.5	17.4	2.7			109
29	16		11.0	32.3	37.5	16.2	2.2	0.7		136
30	18		0.6	12.2	36.1	30.3	14.8	2.0	4.0	153
31	16		15.4	40.9	26.7	13.4	3.5			142
32	14	0.7	18.6	35.7	29.3	13.5	1.4	0.7		140
33	18		13.2	30.2	41.9	12.4	1.5	0.8		129
34	18		12.0	38.7	31.3	12.7	3.3	2.0		150
35	16		13.2	40.4	34.4	9.3	2.6			151
36	18		14.8	25.8	45.2	11.0	3.2			155
37	16		10.9	29.2	35.3	18.4	5.4	0.7		147
38	18		3.8	31.3	39.7	16.8	6.1	2.3		131
39	18		11.6	36.8	33.5	14.8	3.2			155
40	18		1.8	6.7	29.7	29.7	20.0	7.9	4.2	165
41	18		5.8	22.4	35.9	29.4	5.8	0.7		156
42	16		5.7	22.9	45.7	20.9	2.8	1.9		105
43	16		5.0	33.1	40.3	14.4	5.0	1.4	0.7	139
44	18		10.9	24.6	40.4	19.2	4.8			146
45	18		3.4	24.3	23.0	33.8	10.8	2.7	2.0	148
46	16	0.7	6.0	15.9	42.3	28.4	4.6	1.3	0.7	151
47	16	0.7	22.8	30.9	32.2	8.0	4.7	0.7		149
48	16		14.9	38.8	32.8	11.9	0.8	0.8		134
49	16		9.0	36.8	28.4	21.5	4.2			144

It will be noted from the table that all but one of the five 14-rowed ears produced some 10-rowed ears, while only one of the sixteen 18-rowed ears produced any ears with 10 rows. Also that the 14-rowed ears produced only a small percentage of ears with more than 18 rows, while the 20 and 22-rowed ears produced a large percentage of ears with more than 18 rows.

Nominating ears with 14 rows or less as "small" with 16 or 18 as "medium," and with 20 or more as "large," the following summary of the preceding tabulation may be made:

	Per cent of small ears.	Per cent of medium ears.	Per cent of large ears.
Parent ears with 14 rows	54.1	44.0	1.9
Parent ears with 16 rows	39.9	53.6	6.5
Parent ears with 18 rows	32.5	57.0	10.5
Parent ears with 20 rows	31.8	51.7	16.5
Parent ears with 22 rows	8.5	55.5	36.0

A glance at the table shows that the small ears have a marked tendency to produce small ears, and that the large ears have a tendency to produce large ears. It would seem, therefore, that the grower of dent corn has, in the selection of his seed, an opportunity to produce ears of whatever size may strike his fancy as being ideal for that particular strain or variety.

Some additional data—tabulated below—bearing on the relation between the number of rows in ears of corn and the per cent of grain on those ears are also of interest.

Number of rows.	Number of ears tested.	Average per cent of grain.
14	21	80.4
16	98	81.4
18	53	82.2
20	19	84.4
22	9	83.6

The 200 ears in the above test were selected at random with no reference to the probable size of cob. It will be noted that the average per cent of grain steadily increased from the 14-rowed up to the 20-rowed ears. Above 20 rows the percentage declined, probably because the ears became shorter and because the depth of kernel did not increase proportionately to the diameter of the cob. Further data on this point will be forthcoming anon.

SCIENTIFIC CORN BREEDING

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The plant-breeding experiments as conducted on Fairview Farm have been confined to corn. This experimentation has been going on continuously since 1906 and has resulted in the establishment of a few well-founded facts.

As each succeeding season brings its results certain principles are substantiated in the main; therefore I am able to announce definitely a few things of interest. At the same time, ideas have incidentally suggested themselves, which, when followed up, showed promising results for a year or so, but in the end had to be discarded because they proved to lead to entirely undesirable results.

The temptation to arrive at some definite conclusion after one or two years of experimentation and breeding is very great, especially if the results of the different seasons are very similar, and are such as were anticipated at the beginning. However, by following this same line of breeding for several seasons we are apt to meet with disappointment, as the results of some seasons will prove that our experiment has entirely left the lines we had hoped it would follow and has given some disappointing results. This may be caused by weather conditions, an unfavorable season, chemical action of fertilizers in the soil, or the action of preceding crops, combined with injurious effects of insects. Consequently if a breeder wishes his results to gain acceptance as authentic by the public at large, he must be very conservative in his deductions and not take it for granted that the results of a few seasons will be an average for many years. If he is not careful, that fact will be discovered sooner or later and his results called in question.

I will describe my methods of breeding, calling attention to the results of several seasons, and conclusions therefrom, which may however be open to modification later.

In 1905 I began breeding Reid's Yellow Dent corn by "the ear-to-the-row method," as outlined in Bulletin 100 of the Illinois Experiment Station, and have continued this method of breeding each succeeding season with some modifications. The results of six years of breeding this corn are now in hand. Adding to the results obtained by James L. Reid after years of careful selection, and influencing the type of the ears by crossing and selection, until I have eradicated

the short kernel with the dimple dent, which gave the ear a smooth appearance, there was finally developed a longer kernel of a more pinched type, which gives the ear a rougher appearance, but not so rough as is characteristic of the Leaming corn. In so doing, I have materially increased the yield. The conclusion this led to was that a kernel of medium depth with a large amount of horny material will on the average give the highest yield, and that the yield of an ear of corn having a long, rough, narrow kernel containing a large amount of starch will not compare at all favorably with that of an ear having a kernel of medium length and a well-rounded tip. I attribute this to the fact that the short kernel with a large amount of horny gluten gives the young plant a much more vigorous start than it obtains from the narrow kernel with an abnormal amount of starch. This fact is borne out in the germination test of seed corn, for each year; during the testing of about 12,000 ears of corn for my own fields, the great percentage of corn that showed weak germination was from narrow kernels of extreme length, having a large amount of starch.

In connection with the breeding grounds, there are operated the multiplying fields from which I obtain enough seed for the entire farms. In addition to these, there are the isolated fields called the "champion ten-ear plots," each containing one-half acre. These are separated from all other corn by a distance of 80 rods, as are all my trial and breeding grounds. These half-acre plots are for the development of the ten best ears of the breeding ground of the preceding season. When planting the breeding ears I use only half of the seed on each ear, storing the remaining half where it will not deteriorate.

The following season, after the ten champion ears have been determined, the remaining seed from these ten ears is put together and these small plots planted. This gives seed from ears of corn that are true to type, known to be of early maturity and of good producing qualities, having a small percentage of barren stalks, and having wind resistant qualities and many other excellent characteristics, without the undesirable qualities of many of the weaker ears. From these fields we get seed that, after being removed two years, acts as a stimulant when brought back into the multiplying fields, where there is a danger of planting corn that may have been slightly inbred, as results of self or close pollination.

The breeding grounds for Reid Yellow Dent corn contain seventy-six rows; each row containing one-twenty-sixth part of an acre.

The corn that is planted in these rows is first tested for germination, the length and circumference of each ear is taken and recorded, as well as the number of rows on each ear and the character of the indentation of the kernel. The ear is then weighed, the corn shelled, and the proportion of corn to cob computed.

The size of the germ of the kernel from different parts of the ear is recorded as well as the shape of the kernel. This shape is taken by measuring the length and breadth to thirty-seconds of an inch by caliper rule. However, all the ears are photographed before these measurements are taken. These ears are planted three kernels to each hill. The fields are not fertilized in the least as yet, but only normal conditions of soil exist. The fields are cultivated once a week if weather conditions permit, and they receive the same treatment as that given the commercial fields.

As soon as the fertilization period arrives the alternate end of each row is detasseled instead of alternate rows as is generally the practice, as there is small probability that any of the ears will be fertilized by pollen from tassels on stalks grown from kernels of the same ear. This method allows us to take seed from every row, inasmuch as we do not select ears grown very near the center of the field. After determining the center of the field, I insert 6 feet of smooth wire in the planter wire, thus making a 6-foot space between those hills. The stalks are then detasseled to this point on one row, and beginning on the other side of the 6-foot hill the adjoining row is detasseled to the opposite end of the field.

During the period of fertilization I make direct crossings, by hand pollination, between desirable stalks of different promising rows of productive families, which are of no relation to each other. This year I had the good fortune to anticipate the productiveness of some well-bred rows and made ten crossings in ten rows that produced far above 100 bushels to the acre, and, by so doing, produced ears that are fairly well fertilized. These crossings were made every other day for six days, and better results were obtained than when the crossings were made but once. These ears will be isolated and planted together by the ear-to-the-row method, where they will be allowed to cross-pollinate. Having established some very productive families by the breeding row method, the crossbreeding of the most desirable individuals of these families should produce in years to come a strain of corn that is far superior to anything yet known.

Before husking time arrives, we go through the field about the last of September and select breeding ears for the following year,

from the detasseled halves of each row, of early maturity, growing at the right height from the ground, and from standing stalks in hills containing two or more stalks each. In order to be able to tell from which row these ears have been taken they are numbered before being placed in the drying house. The remaining corn is then husked separately about the last part of October, or as soon as the corn is ready for cribbing purposes. After weighing the amount of corn taken from each row, the ears are counted, their average weight determined, the seed ears selected and counted. The number of barren stalks found in each row is also recorded.

I have adopted a system of measurements of the ears planted in the breeding grounds, for the purpose of ascertaining whether the yield is influenced by the number of rows of kernels on an ear, by the character of the dent, by the percentage of corn to cob, by the size of the germ, or by the shape of the kernel. Following is a tabulation of the yields of the ears having the different characteristics.

TABLE 1.—*Comparison of yields of ears with different numbers of rows of kernels for a series of years.*

Variety and year.	Number of rows of kernels. 16	18	20	22	Variety and year.	Number of rows of kernels. 16	18	20	22
	Reid Yellow Dent.					Johnson County White.			
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*		*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
1906	46.4	48.1	48.8	43.5					
1907	80.2	82.9	80.8	77.8	1907	79.7	85.1	86.0	81.2
1908	61.5	66.0	61.5	65.0	1908	62.8	68.7	72.7	60.0
1909	62.7	67.5	72.0	....	1909	79.6	85.6	73.0	....
1910	95.1	92.1	98.1	95.4	1910	81.0	88.1	87.3	79.0

It will be noticed that in comparing the yields of corn of both varieties for the different years, that ears containing twenty rows gave the heaviest yield five different times, and that the ears having eighteen rows gave the maximum yield four different times, while not once during the experiment did ears containing any other number of rows yield the most. After a period of experimentation of five years' duration it is safe to conclude that for these two varieties of corn, it is not advisable to plant corn from ears not having eighteen or twenty rows to the ears.

The way in which the yield is influenced by the size of the germ may be seen from an experiment which has been carried on for four years with each variety, and it is interesting to note the constancy

with which the small-germ kernels of the Reid corn give the best results, whereas in the case of the Johnson corn the kernels having the large germ prove the most satisfactory.

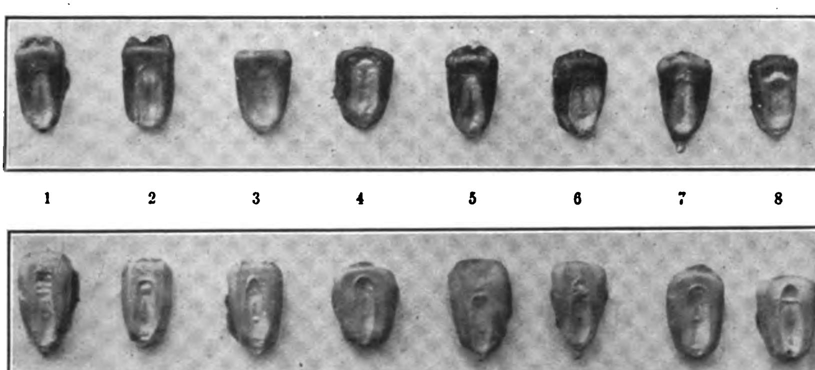
TABLE 2.—*Comparison of yields of kernels with large and small germs.*

Year.	Reid Yellow Dent.		Johnson County White.	
	Germs large.	Germs small.	Germs large.	Germs small.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*
1907	79.4	84.2	86.7	80.0
1908	62.8	64.5	68.1	66.0
1909	66.0	74.3	75.7	70.0
1910	97.3	97.7	86.7	85.6

It will be noticed that in some years the difference in yields of corn having the various characteristics indicated was very marked, while in 1910 the yields were nearer together than at any other time.

The most interesting of all my plant-breeding experiments has been the one by which I have determined the correlation between the yield and the shape of the kernel. This work was begun in 1907

JOHNSON COUNTY WHITE, 1910.



REID'S YELLOW DENT, 1910.

CHARACTER OF KERNELS WHOSE MEASUREMENTS ARE TABULATED IN TABLES 3 AND 4. Numbers in illustration correspond with numbers in tables.

with my two standard varieties of corn and the results have shown that the kernels giving the best yields to the acre are very similar in appearance, shape, and measurements. In the year 1910 I made a new photograph of the kernels used, giving a closer study to the small variations, taking measurements accurate to a thirty-second of an inch, and, comparing these results with those of past years. In

both varieties of corn, the kernel of ideal shape, which tapers slightly and has the square shoulders and full tip, has been giving the best results. Not once since beginning the experiment has an ill-shaped kernel on the average out-yielded the ideally shaped kernel. The kernels of the Reid corn giving the best results were eighteen-thirty-seconds of an inch long by eleven-thirty-seconds of an inch wide, as well as twelve-thirty-seconds of an inch wide, at the crown. The proportion of length to width was thus about 3 to 2, or, in other words, the width proved to be about two-thirds the length of the kernel. In the case of the Johnson corn the kernel giving the best results measured twenty-one-thirty-seconds of an inch long by eleven-thirty-seconds and twenty-thirty-seconds by eleven-thirty-seconds, thus being somewhat longer than the Reid kernel, but the width about the same. This is shown more fully in Table 3. Reference to the illustration will give a clear idea of the shape and structural characteristics of the kernels.

TABLE 3.—*Average measurements of kernels of two varieties of corn.*

[Measurements in thirty-seconds of an inch.]

Character.	Reid Yellow Dent.							
	Ear No. 1	Ear No. 2	Ear No. 3	Ear No. 4	Ear No. 5	Ear No. 6	Ear No. 7	Ear No. 8
Length kernel ...	20	19	18	17	18	18	18	17
Width kernel	10	11	12	12	10	11	11	10
	Johnson County White.							
	Ear No. 1	Ear No. 2	Ear No. 3	Ear No. 4	Ear No. 5	Ear No. 6	Ear No. 7	Ear No. 8
Length kernel ...	21	19	20	18	21	19	20	19
Width kernel	11	10	11	12	12	11	12	12

In all cases however, the square-shouldered kernel, showing a small amount of space betweem the rows at the crown and tip, was in evidence when considering the yield, as appears in Table 4, in which the yields of the respective ears from Table 3 are given for a period of four years.

I am now endeavoring to establish a new variety of white corn by crossing a variety called Reid White Dent, which has a short, heavy, early-maturing ear, with the Johnson County White, which has a long, heavy, late-maturing ear. By planting in alternate rows, detasseling one variety, and taking seed from that, I have found that

in accordance with the Mendelian theory the F_1 generation produces an ear very much to my liking—an ear that is about of an average length, also of early maturity, thus combining the desirable characteristics of both varieties.

TABLE 4.—*Per acre yields of ears having kernels of stated measurements.*

Year.	Reid Yellow Dent.							
	Ear No. 1	Ear No. 2	Ear No. 3	Ear No. 4	Ear No. 5	Ear No. 6	Ear No. 7	Ear No. 8
1907	77.0	81.7	87.1	88.8	....	....	....	....
1908	64.5	64.5	66.5	64.2	....	....	....	....
1909	58.4	71.0	63.0	68.2	....	....	....	....
1910	92.1	94.3	96.1	98.4	104.7	90.5	90.9	96.1

Year.	Johnson County White.							
	Ear No. 1	Ear No. 2	Ear No. 3	Ear No. 4	Ear No. 5	Ear No. 6	Ear No. 7	Ear No. 8
1907	81.2	85.0	84.0	80.5	84.0	....	....	....
1908	69.0	72.0	60.0	71.4	64.0	....	....	....
1909	66.9	68.2	82.4	80.8	62.0	....	....	....
1910	80.0	82.0	89.3	63.3	89.6	87.2	78.5	89.6

An attempt during the past year to increase the yield by producing a greater percentage of stalks bearing two ears each resulted in one instance in increasing the percentage of such stalks to 23.5 per cent and in another to 21.1 per cent in rows 40 rods long. One of these rows contained 250 stalks and the other 288 stalks, of which 58 stalks in one row and 61 in the other produced each two well developed ears. A good percentage of these stalks produced 2 pounds of corn, and yet I am inclined to believe that only the same amount of plant food was taken from the soil that is consumed by the stalk bearing one ear. The difference between the two stalks was evidently due to a change in the proportion of nutriment going into the grain and the leaves, as some of the two-ear stalks did not have as much foliage as did other stalks bearing one ear.

A most interesting experiment has been with a new variety of corn which an enterprising newspaper reporter named the "Cobless Corn," which name seems to cling to it through all its evolutions. This variety started from a mutation found in a field of Johnson County White corn several years ago, and under scientific breeding and isolation had developed an ear as long as 14 inches, with twenty rows of kernels, having a cob so small that its weight is only 3 per cent of that of the entire ear. Each kernel is enclosed in a husk of its

own. Professor Mumford of the University of Illinois recommends this corn very highly as a variety adapted for feeding purposes, on account of the small amount of cob, and because the roughage is along with the grain. This variety is now being crossed with a standard white variety, the object being the reduction of the size of the cob in the large white corn and the elimination of the husk on the kernel of the other, and I have been rewarded with a considerable measure of success. The "Cobless Corn" shows a great tendency to mutate, and in following some of its variations has developed stalks of corn having no ear at all, all the grain being found in the tassel at the top of the stalk. Some of these tassels when gathered weigh as much as 2 pounds, having round kernels of corn hanging in festoons from the spikes of the tassel.

CORRELATION OF CHARACTERS IN OATS, WITH SPECIAL REFERENCE TO BREEDING[a]

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The breeding of oats has received attention from a number of experimenters within the last several years, yet the yields and the quality of the oats now being produced are not what they should be or can be made to be. Much more breeding work is necessary in order that higher yields and better grades of oats may be secured.

This paper deals in a statistical way with some of the factors which must be taken into consideration if breeding operations are to be successful in improving the oat crop. In it an attempt will be made to determine the relations of some of these important factors to each other, with the thought that in the process some of the questions which are continually confronting the experimenter may come a little nearer solution.

Such questions as the following will be considered:

1. Are the tallest plants the heaviest yielders?
2. Do the tallest plants produce the best-yielding heads?
3. Do the tallest plants produce the heaviest kernels?
4. As the number of culms per plant increases does the total yield per plant increase?

[a] Paper No. 16, Department of Plant Breeding, Cornell University, Ithaca, New York.

5. As the number of culms per plant increases is there an increase or decrease in the average number of kernels produced by each culm?

6. As the number of culms per plant increases does the average weight of grain produced by the culms of the plant increase or decrease?

7. As the number of culms per plant increases do the individual kernels decrease or increase in weight?

8. As the average number of kernels produced by the culms of a plant increases do the individual kernels become larger or smaller?

In the attempt to answer these questions data taken on 500 oat plants, grown as a pure line during the summer of 1909, will be considered. This line is a selection from the variety known as Sixty-Day oats. The data have been arranged in tables in such a way as to show the correlation of some of the most important factors to one another. Individual plants, and not individual culms, are used as the units in the calculations. The 500 plants dealt with, then, are composed of 1974 culms.

The data made use of in these tables are: (1) The average height of the culms of the plants, measured from the base of the culm to the base of the apical spikelet. All culms of a plant are measured separately and the sum of these heights is divided by the number of culms making up the plant. (2) The number of culms produced by each plant. (3) The total weight of grain produced by each plant, expressed in grams. (4) The average weight of grain produced by each culm of the plant, found by dividing the total weight of grain produced by the plant by the number of culms of the plant, and expressed in decigrams. (5) The average weight of the individual kernels on each plant, obtained by dividing the total weight of grain produced by the plant by the number of kernels on the plant, and expressed in milligrams. (6) The average number of kernels produced by each culm of the plant, found by dividing the total number of kernels produced by the plant by the number of culms making up the plant.

To show the method of constructing a correlation table let us observe Table 1, which is constructed to show the correlation of the average height of the culms per plant, in centimeters, as subject, to the total yield of plant, in grams, as relative. It will be seen that differences in average height of culms are denoted by horizontal lines parallel to a base line. The highest class of culms, or culms ranging from 90 to 95 cm. are placed in the first space above the base line, and the other classes of culms, as their height decreases, are placed in the con-

secutive spaces increasing in distance from the base line. The shortest culms, or those between 40 and 45 cm. in height, are arranged in the top space, or space farthest from the base line.

Lines perpendicular to the base line mark off in the table differences in yield. The first space at the left shows a yield of 1 gram or less for the whole plant. The second space from the left margin shows a yield above 1 gram and up to and including 2 grams, and so on until the last space is reached, which indicates a yield above 13 and including 14 grams for the plant. Individuals are placed in the table according to their values in regard to these two factors under consideration. If the average height of culms is, for instance, 56 cm., and the yield is 0.9 gram, the individual would be placed in the square which is the fourth from the top of the table and the first from the left margin. The total number of individuals in the population which thus fall in any square of the correlation table is shown by the figure in the square. At the bottom and at the right of the table the total individuals in the different classes are given.

That factor whose classes are arranged on the lines parallel to the base is known as the subject of the correlation table, while the factor with which it is compared, and which is therefore divided into classes by the perpendicular lines, is known as the relative of the correlation table.

The means, standard deviations, coefficients, and other constants, are determined by the use of mathematical formulae which mathematicians have worked out for this purpose.

In the course of this paper frequent reference will be made to the constants determined by Dr. E. P. Humbert at the Cornell Station, which have not yet been published. Dr. Humbert worked with two pure lines, using individual culms, and not individual plants, as units. In one line, which will be referred to as A, he dealt with 825 culms; in the other, which will be designated as B, he dealt with 406 culms. These lines were grown in 1908. Data taken on the progeny of line A, grown in 1909, furnish the material for this paper.

Reference will also be made to the work of Mr. L. R. Waldron, published in the *American Naturalist*, January, 1910. In this work Waldron deals with 1000 oat culms. "In nearly all cases, each head-bearing culm," used by him, "represented an entire plant." The oats used by Waldron were of one variety, but were not a pure line, containing, according to his statement, "various races, or biotypes." The name of the variety is not given, but it was not the Sixty-Day.

The correlation tables which have been constructed will now be considered.

In Table 1 the correlation which exists between the average height of culms per plant in centimeters, as subject, and the total yield per plant in grams, as relative, is shown. The correlation is 0.6886 ± 0.0159.[b] This is a considerable correlation between these two factors. It indicates that the tall plants are on the average much better yielders than the shorter ones.

Humbert found, when dealing with height of culm, as subject, and yield of culm, as relative, a correlation in line A of 0.685 ± 0.012; and in line B a correlation of 0.682 ± 0.018. Both of these agree remarkably well with the results shown in Table 1.

TABLE 1.—*Correlation in oats.*

Average height of culms per plant in centimeters, subject; total yield of plant in grams, relative. $r = 0.6886 \pm 0.0159$.

Average height of culms per plant, in centimeters.	Total yield of plant, in grams. 0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	Totals.
40–45	1														1
45–50	2	1													3
50–55	5	3													8
55–60	1	6	4												11
60–65	7	19	9					1							36
65–70	3	18	26	12	1										60
70–75	4	10	42	20	10	3	2	1		1	1				94
75–80	2	4	14	38	23	6	5	5						2	99
80–85			1	22	32	19	11	10	5			1	1		102
85–90		1		4	13	17	17	9	4	1	2				68
90–95					2	2	5	5	1		2	1			18
Totals.	25	62	96	96	81	47	40	31	10	2	5	2	1	2	500

In Table 2 the correlation which exists between the average height of culms per plant in centimeters, as subject, and the average yield per head of the plant in decigrams, as relative, is shown. The correlation is 0.8424 ± 0.0088, a very high correlation, which indicates that all culms of a tall plant are, on the average, heavy yielders, and would tend to show that any head from such a plant might be selected for high yield. It does not show that tall individual culms from plants averaging low in height may be selected for high yield.

[b] The coefficient of correlation is denoted by r, and always has some value between $+1$ and -1. In the case $r=+1$ the correlation is perfect, and the two characters are related as cause and effect. If $r=-1$ there is perfect negative correlation, the characters being mutually exclusive. If $r=0$ there is no correlation, and it is indicated that the characters move independently of each other.

TABLE 2.—*Correlation in oats.*

Average height of culms per plant in centimeters, subject; average yield of heads per plant in decigrams, relative; $r = 0.8424 \pm 0.0088$.

Average height of culms per plant, in centimeters.	Average yield of heads, per plant in decigrams.																		Totals.
	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	
40-45	1																		1
45-50	1		1	1															3
50-55		2	4	2															8
55-60		1	2	1	7														11
60-65	1			8	9	9	6	3											36
65-70				2	11	9	26	8	3	1									60
70-75				2	6	13	18	20	17	11	5		1	1					94
75-80						1	6	18	32	21	14	4	1	2					99
80-85	1							4	12	20	24	22	8	8	2		1		102
85-90									1	4	11	12	17	14	3	3	3		68
90-95										1	1	1	3	2	5	2	2	1	18
Totals...	4	3	7	16	33	32	56	53	65	58	55	39	30	27	10	5	6	1	500

In Table 3 the correlation which exists between the average height of culms per plant in centimeters as subject, and the average weight of kernels per plant in milligrams, as relative, is shown. The correlation is 0.2188 ± 0.0287, a correlation of inconclusive value. Humbert found in line A a correlation of 0.552 ± 0.016; in line B a correlation of 0.506 ± 0.025, when height of culm in centimeters was considered as subject and average weight of kernels in decimilligrams as relative.

TABLE 3.—*Correlation in oats.*

Average height of culms per plant in centimeters, subject; average weight of kernels per plant in milligrams, relative. $r = 0.2188 \pm 0.0287$.

Average height of culms per plant, in centimeters.	Average weight of kernels per plant, in milligrams.												Totals.
	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	
40-45								1					1
45-50				1			1	1					3
50-55							4		3	1			8
55-60							3	5	2	1			11
60-65	1	1				3	5	7	12	6	1		36
65-70					2	3	5	20	20	9	1		60
70-75		1	1			1	8	31	28	16	7	1	94
75-80						1	10	31	32	18	7		99
80-85							8	22	48	19	2	3	102
85-90				1			3	14	36	7	7		68
90-95						1		5	9	2		1	18
Totals..	1	2	1	2	2	9	47	137	190	79	25	5	500

Waldron, on the other hand, found for the same factors a negative correlation of -0.404 ± 0.017.

The results just cited are of considerable interest to breeders. If the results of Waldron hold, then "the experimenter selecting the large grains is not selecting from what is commonly considered the best plants, and vice versa," but is selecting from the shorter plants. The result here obtained, a correlation of about 22 per cent, shows that the heavy kernels are not produced as a rule by the shorter plants. The results of Humbert indicate that the larger kernels are obtained from the larger culms, or from those which are usually considered better for breeding purposes. It may be restated here that the results reported in this paper, and those obtained by Humbert, are with a variety different from that used by Waldron. The former differ also in being a pure line. Further data on the influence of size of seed and size of the mother plant on the offspring will be of interest in this regard.

TABLE 4.—*Correlation in oats.*

Number of culms per plant, subject; total yield of plant in grams, relative. $r = 0.8496 \pm 0.0084$.

Number of culms per plant.	Total yield of plant, in grams. 0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	Totals.
1	12	1													13
2	13	28	8	1											50
3		24	54	31	6										115
4		8	34	56	56	32	11	1							198
5		1		8	16	13	17	8	1						64
6					3	2	5	12	7		2				31
7							6	8	1	1	2		1		19
8							1	1	1	1	1	2			7
9								1						1	2
10															0
11														1	1
Totals.	25	62	96	96	81	47	40	31	10	2	5	2	1	2	500

In Table 4 the correlation which exists between the number of culms per plant, as subject, and the total yield per plant in grams, as relative, is shown. The correlation is very high, being 0.8496 ± 0.0084. This indicates that as the number of heads borne by the plant increases the total yield of grain by the plant also increases, with quite unifrom regularity.

In Table 5 the correlation which exists between the number of culms per plant, as subject, and the average yield of the heads per

plant in decigrams, as relative, is shown. The correlation here is 0.4005 ± 0.0253. This indicates that on the average as the number of culms to the plants increases the amount of grain obtained from each culm increases.

TABLE 5.—*Correlation in oats.*

Number of culms per plant, subject; average yield of heads per plant in decigrams, relative. $r = 0.4005 \pm 0.0253$.

Number of culms per plant.	Average yield of heads per plant in decigrams: 1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	Totals.
1	1	....	....	1	1	3	3	3	....	....	....	....	....	....	....	....	1	....	13
2	3	3	3	5	8	3	7	5	5	4	2	....	1	1	....	....	....	....	50
3	....	....	....	5	14	11	16	20	12	14	12	5	....	4	2	....	....	....	115
4	....	....	3	5	10	12	22	17	29	27	22	18	11	10	5	3	3	1	198
5	....	....	1	....	....	3	5	4	12	6	7	7	10	5	3	1	....	....	64
6	....	....	....	....	....	....	3	....	2	....	8	8	5	3	....	1	1	....	31
7								2	4	6	2	1	1	2	....	....	1	....	19
8	....	....	....	....	....	....	....	1	1	1	1	....	2	1	....	....	....	....	7
9	....	....	....	....	....	....	....	1	....	....	....	....	....	1	....	....	....	....	2
10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0
11	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	1
Totals.	4	3	7	16	33	32	56	53	65	58	55	39	30	27	10	5	6	1	500

In Table 6 the correlation which exists between the number of culms per plant as subject, and the average weight of kernels per plant in milligrams, as relative, is shown. The correlation here is practically

TABLE 6.—*Correlation in oats.*

Number of culms per plant, subject; average weight of kernels per plant in milligrams, relative $r = 0.0003 \pm 0.0302$.

Number of culms per plant.	Average weight of kernels per plant, in milligrams: 8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	Totals.
1	....	....	....	1	....	....	....	2	7	2	1	....	13
2	1	1	....	....	....	2	6	11	14	10	4	1	50
3	....	....	....	....	1	....	14	30	41	18	8	3	115
4	....	1	1	....	1	4	17	51	80	35	8	....	198
5	....	....	....	1	....	3	5	22	25	8	....	....	64
6	....	....	....	....	....	....	....	10	16	3	1	1	31
7	....	....	....	....	....	....	3	7	4	3	2	....	19
8	....	....	....	....	....	....	2	4	1	....	....	....	7
9	....	....	....	....	....	....	....	....	1	....	1	....	2
10	....	....	....	....	....	....	....	....	....	....	....	....	0
11	....	....	....	....	....	....	....	....	1	....	....	....	1
Totals..	1	2	1	2	2	9	47	137	190	79	25	5	500

zero, being 0.0003±0.0302. This indicates that large kernels are obtained from plants with one, few, or many culms, indiscriminately; that neither the plants with many culms nor those with few have a monopoly of the large or small kernels.

In Table 7 the correlation which exists between the number of culms per plant, as subject, and the average number of kernels of the culms per plant, as relative, is shown. The correlation is of positive value, being 0.4226±0.0248. This is again of value to breeders in that it shows that the more vigorous plants, as indicated by the production of culms, tend on the average to produce to a large extent a greater number of kernels in each head.

TABLE 7.—*Correlation in oats.*

Number of culms per plant, subject; average number of kernels per culm per plant, relative. $r = 0.4226 \pm 0.0248$.

Number of culms per plant.	Average number of kernels per culm, per plant.											Totals.
	10 20	20 30	30 40	40 50	50 60	60 70	70 80	80 90	90 100	100 110	110 120	
1	1	1	2	7	1	......	......	......	1	......	......	13
2	5	7	9	12	6	8	2	1	......	......	......	50
3	......	4	18	24	35	19	11	4	......	......	......	115
4	......	5	15	36	43	38	25	23	9	3	1	198
5	......	1	......	4	15	14	13	10	6	1	......	64
6	......	......	......	2	4	1	15	7	......	2	......	31
7	......	......	......	1	3	7	6	......	1	1	......	19
8	......	......	......	......	1	1	2	3	......	......	......	7
9	......	......	......	1	......	......	1	......	......	......	......	2
10	......	......	......	......	......	......	......	......	......	......	......	0
11	......	......	......	......	......	......	1	......	......	......	......	1
Totals..	6	18	44	87	108	88	76	48	17	7	1	500

In Table 8 the correlation which exists between the average number of kernels of the culms per plant, as subject, and the average weight of the kernels per plant in milligrams, as relative, is shown. The correlation is 0.1226±0.0297, which is small, and, perhaps, should be considered as no correlation at all, or at most as meaning little. This would tend to indicate that the number of kernels produced by a culm is a matter of indifference when selecting for weight of kernel. The large kernels are about as likely to be found in a head which produces few kernels as in a head which produces many.

Waldron found a strong negative correlation, amounting to −0.595 ±0.013, existing between the average weight of kernel in decimilligrams, as subject, and the number of grains per head, as relative.

TABLE 8.—*Correlation in oats.*

Average number of kernels per culm per plant, subject; average weight of kernels per plant in milligrams, relative;. $r = 0.1226 \pm 0.0297$.

Average number of kernels per culm, per plant.	Average weight of kernels per plant, in milligrams. 8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	Totals.
10–20				1			2	1	1	1			6
20–30	1						5	4	6	1	1		18
30–40						1	4	15	15	8	1		44
40–50		2	1		1	4	7	23	26	17	6		87
50–60					1	2	8	33	32	25	5	2	108
60–70						1	13	22	36	12	4		88
70–80						1	4	19	38	8	5	1	76
80–90							4	14	22	5	1	2	48
90–100				1				5	7	2	2		17
100–110								1	6				7
110–120									1				1
Totals..	1	2	1	2	2	9	47	137	190	79	25	5	500

His results, therefore, tend to show that as the number of grains per head increases or, in other words, as the size of head, with reference to grains, increases, the smaller the average weight of kernel. This result does not coincide with that shown in Table 8, where it is indicated that the larger kernels are not produced by the smaller plants.

Humbert found in line A a positive correlation between number of grains, as subject, and average weight of grains in decimilligrams, as relative, of 0.300 ± 0.021. In line B he found a positive correlation of 0.418 ± 0.027. These results show that, as the head increases in size, in reference to grain, the size of the kernels increases also.

The results obtained by Humbert in line A, working with single culms of a pure line as individuals, and those given in this paper, obtained by working with the succeeding generation of the same pure line, with plants as individuals, agree in the main. The correlations reported in this paper are smaller than those obtained by Humbert in two cases, and about the same in the third, and also agree in being positive in all cases. Whether the differences in amount of correlation, where differences exist, are due to place variation or to the differences in procedure is not decided. When these results are compared with those obtained by Waldron, striking dissimilarity is at once observed. The correlations obtained by him for the factors dealt with here were large, and negative.

At present we can only ask: Are these differences due to the varieties used, or have pure lines had some influence on the results, or is

there yet some other factor entering in which has not been considered? Further work must be done to determine these points.

With reference to the results as reported in this paper, it has been shown in Tables 4 to 7 that as the number of culms per plant increases there is a correlated increase also in (1) the total yield of grain per plant, (2) the average yield of the heads per plant, and (3) the average number of kernels produced by the culms of the plant. It has further been shown that as the number of culms per plant increases there is no correlated increase in the average weight of the kernels per plant. In other words, the plants which produce the largest yields and the largest numbers of kernels tend to be the plants which produce the largest numbers of culms, or which bear the largest numbers of heads; and the increase in yield is due to increase in numbers of kernels and not to increase in size of kernels.

These results are of importance to breeders and farmers in that they signify that plants which produce several culms, or which stool, do not do so at the expense of yield. If this holds from year to year and for different varieties, then much stooling is a character to be sought in breeding. After securing a strain which stools largely the rate of seeding could be reduced very considerably with no decrease in yield. It may, however, be found that varieties differ in regard to these correlations, and a non-stooling variety may be found which will yield more and be more satisfactory in other ways. With a non-stooling variety the rate of seeding must, of course, be considerably larger. Before general laws can be formulated in regard to these points the inheritance of the stooling habit should be studied.

In the light of the results reported here what can be said of the process of selecting for seed the heaviest kernels from a lot of oats in bulk without reference to the plants which produced them? In Table 3 it is seen that the heaviest kernels do not as a rule come from the shortest plants; there is an indication that they come from the larger plants more often, yet the correlation is not large and should not be considered as supporting the practice of choosing large seed from bulk grain for sowing. It is shown quite definitely in Table 6 that the larger kernels come from plants with a large, medium, or small number of culms, indiscriminately, yet in Table 4 the largest yields are shown to come from the plants having the largest number of culms. This would seem to condemn the method of selecting the largest kernels for planting without reference to the plants from which they come, until it is shown that the size of seed has more influence on the offspring than the character of the mother plant.

TABLE 9.

Variate.	Mean.	Standard deviation.	Coefficient of variation.
Average height of culms in centimeters.....	76.110 ± 0.277	9.188 ± 0.196	12.07 ± 0.26
Total yield of plant in grams................	4.032 ± 0.068	2.249 ± 0.048	55.78 ± 1.51
Average yield of heads per plant in decigrams....................................	9.748 ± 0.095	3.153 ± 0.067	32.35 ± 0.76
Average weight of kernels per plant in milligrams....................................	16.180 ± 0.039	1.311 ± 0.028	8.10 ± 0.17
Number of culms per plant................	3.948 ± 0.043	1.415 ± 0.030	35.84 ± 0.86
Average number of kernels per culm per plant....................................	59.800 ± 0.557	18.508 ± 0.394	30.95 ± 0.72

TABLE 10.

ORIGINAL RESULTS REPORTED IN THIS PAPER.

Table No.	Subject.	Relative.	Coefficient of correlation.
1	Average height of culms per plant in centimeters	Total yield of plant in grams	0.6886 ± 0.0159
2	Average height of culms per plant in centimeters	Average yield of heads per plant in decigrams	0.8424 ± 0.0088
3	Average height of culms per plant in centimeters	Average weight of kernels per plant in milligrams	0.2188 ± 0.0287
4	Number of culms per plant	Total yield of plant in grams	0.8496 ± 0.0084
5	Number of culms per plant	Average yield of heads per plant in decigrams	0.4005 ± 0.0253
6	Number of culms per plant	Average weight of kernels per plant in milligrams	0.0003 ± 0.0302
7	Number of culms per plant	Average number of kernels per culms, per plant	0.4226 ± 0.0248
8	Average number of kernels per culm per plant	Average weight of kernels per plant in milligrams	0.1226 ± 0.0297
	RESULTS OBTAINED BY WALDRON.		
3	Average weight of grains in decimilligrams	Length of culm in centimeters	−0.404 ± 0.017
8	Average weight of grains in decimilligrams	Number of grains per head	−0.595 ± 0.013
	RESULTS OBTAINED BY HUMBERT.		
1	Height of culm in centimeters	Total yield of culm in centigrams:	
		Line A........................	0.685 ± 0.012
		Line B........................	0.682 ± 0.018
3	Height of culm in centimeters	Average weight of kernels per culm in decimilligrams:	
		Line A........................	0.552 ± 0.016
		Line B........................	0.506 ± 0.025
8	Number of kernels per culm	Average weight of kernels per culm in decimilligrams:	
		Line A........................	0.300 ± 0.021
		Line B........................	0.418 ± 0.027

In Table 9 are given the means, standard deviations, and coefficients of variability, with their probable errors, of the different variates or characters dealt with in this paper.

In Table 10 is given a résumé of the coefficients of correlation embodied in this paper.

SUMMARY

In recapitulation it may be said that the data dealt with in this paper show that tall plants are better yielders than short ones; that all culms of tall plants are, on the average, heavy yielders, and any head from such a plant may usually be selected for high yield; that, contrary to the results of Waldron, the larger kernels are not as a rule obtained from the shorter plants, or from those usually not considered better for breeding purposes; that as the number of heads borne by the plant increases the total yield of the plant also increases; that as the number of culms per plant increases the amount of grain obtained from each culm increases, on the average, to quite a large extent; that large kernels are obtained about equally from plants with many or few culms; that as the number of culms increases the number of kernels borne by each culm increases; that large kernels are as likely to be found in a head which produces few as in a head which produces many kernels, or that the largest kernels are not as a rule found on the plants giving the smallest yield; that there is possibly a difference as regards correlation of characters between different varieties, or between pure lines and varieties.

EFFECT OF FERTILITY UPON VARIATION AND CORRELATION IN WHEAT*

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The study of the correlations of various characters is a very important one and has received increased attention during the last few years, especially from biologists who are working from the statistical standpoint. While correlations have long been studied in a general way, it is only by statistical methods that such relationships can be accurately measured and determined.

In the breeding of cereals, many data have been obtained upon

* Paper No. 18, Department of Plant Breeding, Cornell University, Ithaca, N. Y.

the question of large and small seed as associated with yield. The results, however, are conflicting, and the question remains a mooted one. The influence of nutrition upon the size of the seed is not definitely known any more than is the influence of the size of the seed upon the progeny.

Nutrition has long been considered one of the most important factors influencing the variability of plants. Darwin[a] states that "Of all the causes which induce variability, excess of food, whether or not changed in nature, is probably the most powerful." He also observed the correlation of characters in connection with their variability.

Before Darwin, Knight[b] was led to the belief that variation in both plants and animals was due to a more abundant supply of nourishment or more favorable climate, than was natural to the species.

Schleiden[c] was also inclined to this view, especially in regard to the inorganic elements of food.

De Vries[d] devotes considerable space to the question of the influence of nutrition upon the variability of plants. He regards nutrition, in the widest sense, as the basis of all variation. He sees no distinction between nutritional modifications and individual variations. In general, favorable conditions tend to give plus variations while unfavorable conditions give minus variations. Selection, according to DeVries, is the choice of the best nourished individuals the younger the plant, the greater the influence of external conditions upon its variability. "The nutrition of the seed on the mother plant, has in many cases, at any rate, a greater effect on variability than nutrition during germination and vegetative life itself." DeVries sowed poppies on three beds, one of sand, one of garden soil and one of richly manured soil. This species is quite variable. One form is distinguished by the conversion of the inner stamens into carpels. These carpels may vary in number from a few to 150 or more. In the experiment referred to, the number of these carpels increased markedly as the fertility increased.

Rheinol[e] found that the number of stamens of *Stellaria media* increased as the food supply increased and that the poorly fed plants were less variable than those more highly nourished.

[a] *Animals and Plants under Domestication*, II, p. 236.
[b] *Treatise on the Culture of the Apple.*
[c] *The Plant.* (1848)
[d] *The Mutation Theory.*
[e] Die Variation in Andröceum der Stellaria media Cyr., *Bot. Zeit.* (1903) p. 159.

Miss Tammes[f] studied the effect upon flax, of good and poor soil and thin and thick plantings. Her conclusion is that the more favorable growth conditions tend to lessen variability. She states that the variability is least under the most favorable or the most unfavorable conditions. The greatest correlations occurred upon the poor soil.

E. Davenport,[g] in his study of ears of corn grown upon plots of different degrees of fertility, concludes that variability is not greatly influenced by fertility.

Love[h] studied variation in peas, buckwheat, corn and asters. His conclusions from the data presented were that, in general, increase in nutrition gave an increase in variability and that correlations decreased as fertility increased.

Humbert[i] arrived at the conclusion that an increase of food supply was coupled with a decrease in variability and an increase in correlation.

Clark[k] found that with timothy the mean values were highest under most favorable conditions. Variations due to seasonal conditions were quite marked.

The present paper is a preliminary report of some work with wheat. As stated before, the question of correlations is an important one, especially from the breeding standpoint, and any data which will shed light upon the problem should be of some value.

The wheat, upon which the data for this paper was taken, is the variety known as Dawson's Golden Chaff. The seed was from a mixed population and was planted in the fall of 1909 upon three plots of different degrees of fertility. The seed were planted far enough apart so that individual plants could be distinguished. The first of the plots was dug out to a depth of one foot, the sides lined with boards and then filled with sand. The second plot was ordinary garden soil without treatment. The third was of the same soil but fertilized in 1909 with manure at the rate of eighty tons per acre and with acid phosphate at the rate of 900 pounds per acre. The garden in which these plots are located is river bottom land and is quite fertile. An analysis of the soil of these plots is shown in Table 1.

[f] *Die Flachsstengel Natuurk. Verhandel. Holland. Maatsch. Wetensch.* Haarlem., 3, ser. 6 (1907) No. 4.

[g] Illinois Ex. Sta. Bul. 119.

[h] Studies of Variation in Plants, Cornell Uni. Agr. Ex. Sta. Bul. 297.

[i] A quantitative Study of Variation, Natural and Induced in Pure Lines of Silene Noctiflora. *Zeitschrift für induktive Abstammung—und Vererbungslehre* 1911 Bd. iv, Heft 3 u. 4.

[k] Cornell Agr. Ex. Sta., Bul. 279.

TABLE 1.—*Analysis of soil from three plots of different degrees of fertility.*

	Ordinary.	Sand.	Manured.
	Per cent.	*Per cent.*	*Per cent.*
K_2O	0.57	0.29	0.76
P_2O_5	0.275	0.125	0.35
N	0.280	0.03	0.44
Organic Matter	10.40	01.66	15.20
Acidity	15.00 cc.	Alk.	20.00 cc.
Moisture	1.80	0.13	2.57

NOTE.—Acidity number is the number cubic centimeters of $\frac{N}{25}$ $Ca(OH)_2$ required to neutralize the acidity of 10 grams of the soil.

The wheat was harvested by individual plants and the following data was taken for each plant, using the culm as the basis for measurement: The total number of culms produced; the total weight of the several culms, straw and grain, in grams; the height of culms in centimeters measured from the base to the tip of the spike; the length of the spike in centimeters; the number of spikelets; the number of rudimentary spikelets at the base; the total number of kernels and the weight of the kernels in grams. In the correlation tables following, the averages for plants will be considered except in the correlations between the gross weight of the culm and the weight of the grain from the culm. That is, the average height of plant is found by dividing the sum of the heights of all the culms of the plant by the number of culms. In a like manner the average weight per kernel is found by dividing the sum of the weights of the kernels of each culm by the sum of the numbers of kernels of each culm. The ordinary statistical constants are employed, the short method, as explained by E. Davenport,[1] being used for standard deviation and the coefficient of correlation.

The following points will be considered:

1. The correlation of the average weight of kernel with the number of culms. That is, do the kernels become smaller as the number of culms per plant increases?

2. The correlation of the average weight of kernel with the height of culms. Are the larger kernels from the shorter or taller plants?

3. The correlation between the gross weight of the culm and the net weight of the grain. In other words, is the total weight of the culm an index of the amount of grain it produces?

4. What effect has fertility upon these correlations and upon variability in general?

[1] Principles of Breeding.

Table 2 shows the correlation between the number of culms and the average weight of the kernels of wheat grown upon sand. The correlation in this case is not large but is distinct and positive, amounting to practically 33 per cent.

TABLE 2.—*Correlation of number of culms per plant and average weight of kernels per plant of wheat grown on sand.*

$r = 0.301 \pm 0.027.$

Average weight of kernels per plant, in milligrams.	Number of culms per plant. 1	2	3	4	5	6	7	Totals
2–3	1	.....	.....	.....	.....	.....	.....	1
3–4	.....	.....	.....	.....	.....	.....	.....	0
4–5	5	.....	.....	.....	.....	.....	.....	5
5–6	2	.....	.....	.....	.....	.....	.....	2
6–7	2	.....	1	.....	.....	.....	.....	3
7–8	.....	.....	.....	.....	.....	.....	.....	0
8–9	3	2	.....	1	.....	.....	.....	6
9–10	7	1	2	.....	.....	.....	.....	10
10–11	3	.....	.....	1	.....	.....	.....	4
11–12	6	1	.....	.....	.....	.....	.....	7
12–13	7	2	1	.....	.....	.....	.....	10
13–14	7	2	1	.....	.....	1	.....	11
14–15	17	1	2	.....	.....	.....	.....	20
15–16	7	2	1	1	.....	.....	.....	11
16–17	7	3	.....	.....	.....	.....	.....	10
17–18	10	6	3	1	.....	.....	.....	20
18–19	10	1	.....	.....	.....	.....	.....	11
19–20	18	9	1	2	.....	.....	.....	30
20–21	8	7	1	2	.....	.....	.....	18
21–22	15	8	2	.....	.....	1	.....	26
22–23	15	11	8	1	.....	.....	.....	35
23–24	14	10	5	2	.....	.....	.....	31
24–25	17	9	6	1	.....	.....	.....	33
25–26	9	11	4	.....	.....	.....	.....	24
26–27	9	10	7	2	1	.....	.....	29
27–28	8	12	8	3	.....	.....	.....	31
28–29	8	6	4	3	.....	.....	.....	21
29–30	10	9	1	2	.....	1	.....	23
30–31	4	3	4	2	.....	.....	.....	13
31–32	3	3	1	3	.....	1	.....	11
32–33	2	2	2	1	.....	.....	.....	7
33–34	2	6	2	1	.....	.....	1	12
34–35	3	1	3	.....	2	.....	.....	9
35–36	.....	7	1	.....	1	.....	.....	9
36–37	.....	2	.....	.....	.....	.....	.....	2
37–38	.....	.....	1	1	.....	.....	.....	2
38–39	.....	1	.....	.....	.....	.....	.....	1
39–40	1	1	1	.....	.....	.....	.....	3
40–41	.....	1	.....	.....	.....	.....	.....	1
Totals...	240	150	73	30	4	4	1	502

Table 3 shows the correlation of the same characters of wheat grown upon ordinary soil. Here the amount of positive correlation, a little more than 1 per cent, is so small as to be almost negligible. These results are neither directly contradictory nor are they entirely concordant. The same seasonal conditions may affect the plants of the two plots differently.

TABLE 3.—*Correlation of number of culms per plant and average weight of kernels per plant of wheat grown on ordinary soil.*

$r = 0.013 \pm 0.032.$

Average weight of kernels per plant, in milligrams.	Number of culms per plant.									Totals.
	1	2	3	4	5	6	7	8	9	
9–10	1									1
10–11										0
11–12			1							1
12–13										0
13–14										0
14–15										0
15–16		1								1
16–17		1								1
17–18										0
18–19			1							1
19–20		1		1						2
20–21		1	1							2
21–22			2							2
22–23			3							3
23–24		2	3	2		1				8
24–25	1		2	1		1				5
25–26			6	1	3					10
26–27		5	7	6	3		2			23
27–28	2	1	6	5		1	1			16
28–29		1	16	15	4	1	2		1	40
29–30	1	6	12	11	7	4	2			43
30–31		8	14	17	13	1				53
31–32	2	6	21	25	4	3	1			62
32–33		7	14	15	10	2	3			51
33–34		3	17	15	5	3		1		44
34–35		3	12	4	5	1				25
35–36		2	6	7	1	1	1			18
36–37	1	1	6	2						10
37–38	1	4	3	4						12
38–39			2		2					4
39–40	2	2								4
40–41			2							2
41–42										0
42–43										0
43–44										0
44–45			1							1
Totals....	11	55	158	131	57	19	12	1	1	445

Table 4 shows the correlation between the average height of culms and the average weight of kernels of wheat grown upon sand and Table 5 the correlation of the same characters of wheat grown upon ordinary soil. There is a positive correlation in both cases, amounting to 51 per cent in the first and to 43 per cent in the second. From the data presented in these two tables it is evident that, for this series of plants,

TABLE 4.—*Correlation of average height of culms per plant and average weight of kernels per plant of wheat grown on sand.*

[$r = 0.509 \pm 0.022$]

Average weight of kernels per plant, in milligrams.	Average height of culms per plant.																	Totals.
	13 18	18 23	23 28	28 33	33 38	38 43	43 48	48 53	53 58	58 63	63 68	68 73	73 78	78 83	83 88	88 93	93 98	
2–3							1											1
3–4																		0
4–5	1	1	1	1		1												5
5–6				1							1							2
6–7	1				1	1												3
7–8																		0
8–9	1	1	1	1		1		1										6
9–10		2	1	2	2	1	1		1									10
10–11				1		1						1	1					4
11–12		1	1		2	1	1			1								7
12–13		2	1	1	1	1	1			1		1	1					10
13–14			1	2	1	3	2			1	1							11
14–15		1	2	2	4	3	2	1	2	1	1	1						20
15–16	1		1		1	3	2	1	2									11
16–17			1		1	1		1	5	1								10
17–18		1		1	4	2	1	1	2	5	1	1	1					20
18–19		1		1	2	1			4	1	1							11
19–20		1	1	4	2		2	5	4	2	2	1	4		2			30
20–21				1	1	1	3		6	3	1	1	1					18
21–22				1		2	2	3	6	3	4	4	1					26
22–23				1	1	3	2	2	7	9	1	4	2	3				35
23–24			1			1	3	3	1	5	3	7	4	2			1	31
24–25			1	2	2	2	4	1	5	6	5	4	1					33
25–26			1			3	4	1	3	4	7			1				24
26–27				1	2	4		2	4	4	5	5	1		1			29
27–28			1	1	2	1	2	4	3	1	6	4	2	3	1			31
28–29					1		2	2	3	4	3	2	2	1			1	21
29–30		1	1		1	2	1	2	1	2	2	5	3	1	1			23
30–31						1	1	2		1		1	1	2	4			13
31–32							1		2	5		1		1		1		11
32–33						1	1	1	1	1	1					1		7
33–34								2		2	1	2		4	1			12
34–35								1	1	2		2	1	1		1		9
35–36						1		1	1	1	1		1	1	1		1	9
36–37													1	1				2
37–38										1						1		2
38–39							1											1
39–40										1				2				3
40–41																1		1
Totals..	4	12	16	24	31	42	40	37	64	68	47	47	28	23	11	5	3	502

the heavier kernels are produced by the taller culms. This does not agree with the work of Waldron[m] who found, in wheat, but a slight positive correlation between height of culms and average weight of kernel. His results led to the conclusion that greater or less average

[m] A Suggestion Regarding Heavy and Light Seed Grain, *Amer. Nat.*, vol. xliv, pp. 48–56.

height of culms did not imply any particular weight of kernels. However, as Waldron suggests in regard to his work upon oats, there may be varietal differences which influence these correlations. Clark[n] has pointed out, in the case of timothy, that seasonal variations may influence the coefficients of correlation. A paper by Love[o] which appears elsewhere in this report, indicates that correlation in pure

TABLE 5.—*Correlation of average height of culms per plant and average weight of kernels per plant of wheat grown on ordinary soil.*

[r = 0.480 ± 0.025.]

Average weight of kernels per plant, in milligrams.	Average height of culms per plant. 28–33	33–38	38–43	43–48	48–53	53–58	58–63	63–68	68–73	73–78	78–83	83–88	88–93	93–98	98–103	103–108	108–113	113–118	Totals.
9–10			1																1
10–11																			0
11 12	1																		1
12–13																			0
13–14																			0
14–15																			0
15–16										1									1
16–17									1										1
17–18																			0
18–19										1									1
19–20					1						1								2
20–21				1									1						2
21–22												1		1					2
22–23												2	1						3
23–24					1				1	1	1	1	1	1		1			8
24–25				1	1					1		1	1						5
25–26										1	3	1	2	2	1				10
26–27									1		6	4	8	2	2				23
27–28										1	3	2	5	4	1				16
28–29											3	3	11	11	7	5			40
29–30	1					1			1	3	5	7	10	6	4	3		2	43
30–31										1		13	7	15	9	3	5		53
31–32										1	1	6	8	15	19	10	1	1	62
32–33						1				2	2	5	9	11	10	8	3		51
33–24										1	1	5	2	7	8	12	5	3	44
34–35						1					1	2	6	3	4	5	3		25
35–36						1			1			2	3		3	4	4		18
36–37													2	2	2	4			10
37–38												1	3			3	5		12
38–39													2		1	1			4
39–40												1		1		1		1	4
40–41													1					1	2
41–42																			0
42–43																			0
43–44																			0
44–45														1					1
Totals.	2	....	1	2	3	4	....	....	5	14	27	57	83	82	71	60	26	8	445

lines may differ from those in mixed populations. As stated previously, the data presented in the present paper was taken upon a mixed population.

It may be observed in passing that in every instance the correlation is greater upon the sand plot than upon the plot of ordinary soil.

[n] Cornell Uni. Agr. Ex. Sta., Bul. 279.

[o] A Study of the Large and Small Grain Question.

The correlation between the total weight of the culm and the weight of the grain shelled from the culm, is a very important one from the breeding standpoint. If the gross weight of the plant, including the straw and grain, can be taken as an index of the weight of the grain, then breeding operations may be facilitated to a considerable extent for the selections may be made by comparing the total weights of the plants or rows without shelling and weighing the grain. So far as the writer is aware, no data upon this question has been presented in a statistical way. Some observations have been made in connection with variety tests.

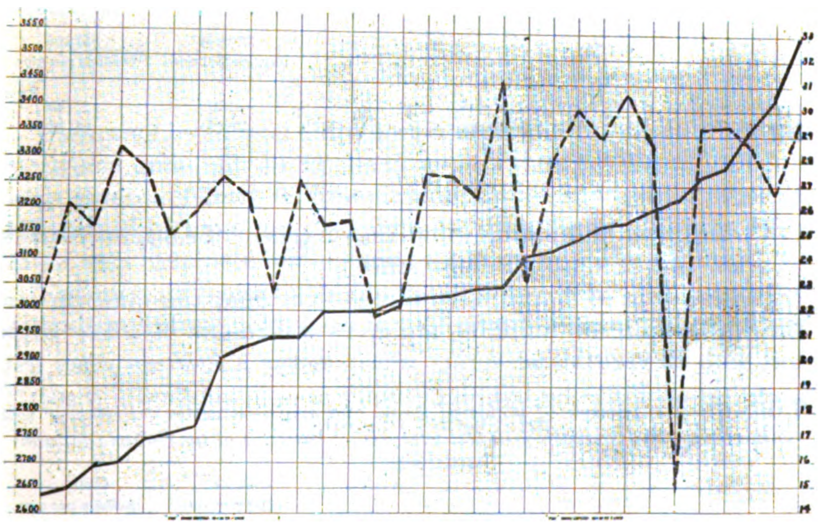

FIG. 1. CURVE SHOWING THE RELATION OF STRAW TO GRAIN OF WHEAT.

Figures at the left are pounds of straw per acre. Figures at the right are bushels of grain per acre. Solid line represents yields of straw arranged in ascending order. Broken line represents corresponding yields of grain. Results of three years' variety tests at the Kentucky Station.

Scherffius and Woosley[p] report the yields of straw and grain of a three years test of some 31 varieties of wheat at the Kentucky Experiment Station. One of the conclusions from this work was "that there is no absolute relation between the yield of straw and grain but that, generally, the highest yields of straw are associated with low yields of grain under normal conditions."

A careful analysis of the data presented does not entirely support this conclusion. In Fig. 1, these results are represented graphically.

[p] Kentucky Ex. Station Bul. 135.

The solid line represents the three year average yields of straw, arranged in ascending order. The broken line represents the corresponding yields of grain. With a few exceptions, it is apparent that, in general, the yields of straw and grain increase together. The one striking exception is so far below the normal that we are led to the conclusion that its growth and development was affected in some abnormal way, perhaps by disease or accident. Omitting the middle point and comparing the 15 highest with the 15 lowest we have the results given in Table 6.

TABLE 6.—*Comparison of yields of straw and grain in wheat. Three years' test at the Kentucky Station.*

	Straw pounds per acre.	Grain bushels per acre.
Average yield of 15 test above the average	3210	27.48
Average yield of 15 test below the average	2847	25.25
Difference	363	2.23

An inspection of this table shows that in general the highest yielders of grain also produce the most straw.

Other data is available which throws light upon this question. In the Ontario Report for 1909, are given the results of a five years test with 22 varieties of spring wheat and of a fourteen years test with 15 varieties of winter wheat. These results are tabulated in Table 7. In both the spring and winter varieties, the highest yields of grain are associated with the higher yields of straw.

TABLE 7.—*Comparison of yields of straw and grain in wheat. Five-year test with spring, and fourteen-year test with winter varieties at the Ontario Station.*

	Straw, tons per acre.	Grain bushels per acre.
Average yield 7 winter varieties above average	3.3	48.8
Average yield 7 winter varieties below average	2.9	45.1
Difference	0.4	3.7
Average yield 11 spring varieties above average	1.9	33.3
Average yield 11 spring varieties below average	1.7	29.7
Difference	0.2	3.6

Noll[q] gives a summary of the variety tests of wheat at the Pennsylvania State College. These tests are 32 in number and range from

[q] Penn. State College, Bul. 94.

1 to 19 years in duration. The weights of straw and grain are given for each of these tests. These results are arranged for comparison in Table 8. An inspection of this table shows that there is a positive correlation between the weight of straw and grain.

TABLE 8.—*Comparison of yields of straw and grain in wheat. Variety tests at Pennsylvania State College.*

	Straw, pounds per acre.	Grain, bushels per acre.
Average yield of 16 tests above the average	3477	30.5
Average yield of 16 tests below the average	3055	29.2
Difference	422	1.3

There may be varietal differences in regard to this relation between straw and grain but the results given in Tables 6, 7 and 8 include a large number of tests, in different localities, extending over considerable period of time, and they are quite consistent. However, all of these tests have been variety tests made under field conditions.

The question comes to the breeder, whether or not this correlation of grain and straw holds good for individual culms or plants. From

TABLE 9.—*Correlation of gross weight of culm and weight of grain per culm of wheat grown on ordinary soil.*

($r = 0.925 \pm 0.004$.)

Gross weight of culms, in grams.	Weight of grain, in grams. 0.0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1.0	1.0–1.2	1.2–1.4	1.4–1.6	1.6–1.8	1.8–2.0	2.0–2.2	2.2–2.4	Totals.
0.5–1.0	5	1											6
1.0–1.5	1	16	3										20
1.5–2.0		6	18	7									31
2.0–2.5			7	33	7	1							48
2.5–3.0			1	17	40	12							70
3.0–3.5			1	2	30	53	20						106
3.5–4.0					7	28	35	13	1				84
4.0–4.5					1	3	20	36	9				69
4.5–5.0						2	4	18	17	4			45
5.0–5.5								2	4	4	2		12
5.5–6.0									2	5		1	8
6.0–6.5												1	1
Totals	6	23	30	59	85	99	79	69	33	13	2	2	500

the plants grown upon ordinary soil and upon manured soil the writer has taken the gross weights of culms and the weights of the grain from the culms. These results appear in Tables 9 and 10. There is an extremely high positive correlation in both instances, amounting in the first to 93 per cent and in the second to 89 per cent. In this series of plants, at least, the gross weight of the plant would have been a safe index of the weight of the grain.

TABLE 10.—*Correlation of gross weight of culm and weight of grain per culm of wheat grown on manured soil.*

($r = 0.890 \pm 0.006$.)

Gross weight of culms, in Grams.	Weight of grain, in grams. 0.0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1.0	1.0–1.2	1.2–1.4	1.4–1.6	1.6–1.8	1.8–2.0	2.0–2.2	Totals.
0.5-1.0	3	1	......	......	......	......	......	......	......	......	......	4
1.0-1.5	1	3	1	......	......	......	......	......	......	......	......	5
1.5-2.0	......	2	18	3	......	......	......	......	......	......	......	23
2.0-2.5	......	1	7	19	4	......	......	......	......	......	......	31
2.5-3.0	......	......	5	21	41	4	......	......	......	......	......	71
3.0-3.5	......	......	......	9	32	49	3	......	......	......	......	93
3.5-4.0	......	......	1	3	20	47	41	1	......	......	......	113
4.0-4.5	......	......	......	......	3	20	48	19	......	......	......	90
4.5-5.0	......	......	......	......	......	4	11	19	7	1	......	42
5.0-5.5	......	......	......	......	......	......	3	3	14	3	......	23
5.5-6.0	......	......	......	......	......	......	......	......	1	2	1	4
6.0-6.5	......	......	......	......	......	......	......	......	......	1	......	1
Totals..	4	7	32	55	100	124	106	42	22	7	1	500

The data presented by the writer in this paper does not offer a great deal of evidence upon the question of the effect of fertility or nutrition upon variability. But since it concerns a fairly large number of individuals and is consistent, it furnishes evidence of some value.

It was observed in connection with the correlation tables that in every instance the coefficient of correlation was greater upon the less fertile plot. In Table 11 are shown the constants for the various characters studied.

An inspection of Table 11 shows some interesting and fairly consistent results as regards variablility. The means increase decidedly as we pass from the sand plot to the ordinary plot. In passing from the ordinary to the highly manured plot the difference is not so decided. Indeed, the mean is increased in the case of the gross

TABLE 11.—*Constants for characters of wheat grown upon plots of different fertility.*

Character.	Mean.	Standard deviation.	Coefficient of variability.
Sand plot, 502 plants:			
Average weight of kernels	22.853 ± 0.213	7.083 ± 0.151	30.994 ± 0.720
Number of culms	1.853 ± 0.028	1.044 ± 0.022	56.341 ± 1.534
Average height of culms	55.061 ± 0.504	16.733 ± 0.356	32.906 ± 0.773
Ordinary plot, 445 plants:			
Average weight of kernels	30.878 ± 0.127	3.987 ± 0.090	12.912 ± 0.297
Number of culms	3.638 ± 0.040	1.258 ± 0.028	34.497 ± 0.867
Average height of culms	93.545 ± 0.391	12.238 ± 0.277	13.082 ± 0.301
Gross weight of culms	3.332 ± 0.032	1.047 ± 0.022	31.423 ± 0.733
Weight of grain	1.090 ± 0.012	0.409 ± 0.009	37.523 ± 0.906
Manured plot :			
Gross weight of culms	3.545 ± 0.028	0.939 ± 0.020	26.488 ± 0.603
Weight of grain	1.074 ± 0.010	0.337 ± 0.007	31.378 ± 0.731

In taking the data for the correlation of the gross weight of the culm with the weight of grain from the culm, the individual culm was used as the basis instead of the plant. Five hundred culms were considered.

weight of culms and decreased in the case of the weight of grain from the culm.

The coefficient of variability is greater in every instance for the plants grown upon the less fertile soil. Here again, the distinction is not so marked between the ordinary and manured plots, as between the sand and the ordinary plots. This is what might be expected, since the coefficient of variability is so strongly influenced by the mean, which in these instances is not so different.

If we measure the variability of these plants by the standard deviation, again we see that it is greatest upon the poorer soil. To be exact, in four cases out of five, the standard deviation is less upon the more highly fertilized plots.

In general, then, we see that the variability of these wheat plants is greatest upon the poorer soil. This is not in accordance with the results reported by Love.[r] He found that in a majority of cases, increased nutrition was coupled with an increase in variability. However, he found less correlation upon good soil where Humbert[s] found the greater correlation. It is very probable that seasonal variations may explain these conflicting results. Definite conclusions cannot be drawn until much more data, extending over a period of years, is amassed.

[r] Studies of Variation in Plants, Cornell Uni. Agr. Ex. Sta. Bul. 297.

[s] A Quantitative Study of Variation, Natural and Induced in Pure Lines of Silene Noctiflora. *Zeitschrift für induktive Abstammung—und Vererbungslehre*, 1911, Bd. iv, Heft 3 u. 4.

SUMMARY

The results discussed with this particular lot of data may be summarized as follows:

1. The original data of wheat used in this study is from a mixed population of the variety known as Dawson's Golden Chaff. The data used in Tables 6, 7 and 8 and in Fig. 1, was derived from sources as stated.
2. There is a slight positive correlation between number of culms and the average weight of kernel. That is, the majority of the heavier kernels are produced by the plants with the larger number of culms.
3. In general, the taller plants produce the heavier kernels.
4. There is an absolute relation between the weight of straw and the weight of grain. This relation is most marked in the case of individuals culms.
5. All correlations are greatest upon the poorer soil.
6. Increased fertility tends to decrease variability.
7. More data is needed before definite conclusions can be drawn.

VALUE OF CONTINUOUS SELECTION AND ITS BEARING UPON HARDINESS IN WINTER WHEAT

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One of the engrossing subjects of breeding is the possibility of producing changes by continuous selection. But a few years ago, it was the common belief that changes could be so produced. As things are going, but a few years will see a radical change in the "mode" of belief so that the common opinion will be against the efficiency of continuous selection.

Continuous selection, baldly stated, is this: May we, by selecting taller and taller wheat plants each year, finally secure a plant that averages taller than the one with which we started?

In 1900, von Rümker of Germany commenced with a small sample of Petkus rye, a variety said to have originated from a single plant. When he started, the plants of one group produced on the average about 63 per cent of green-colored kernels, the remainder being yellow. Another group had plants with 54 per cent of yellow kernels, the

remainder being green-colored. By selecting from year to year the green-colored or the yellow kernels, as the case might be, from the two groups, he finally obtained, in 7 or 8 years, two races breeding pure, or nearly so, to the color selected. Doubtless the end results would have been the same, starting with the contrary groups, but the work would have taken longer. In addition, he succeeded in selecting out a blue-kerneled race, a brown kerneled race and another yellow race, with short, thick kernels. Rye is said to be largely cross-pollinated under ordinary conditions.

In 1896, breeding investigations with corn were begun at the Illinois Experiment Station and the large results have already been presented in the *American Breeders Magazine* (vol. i, p. 15). At that place it was shown that, starting with a single individual, both plus and minus changes had been made in the protein content, and likewise in the oil content, so that now we have a spread of 5 per cent or more between the high and low protein contents of two strains of corn, and about 5 per cent of oil between two other strains. The results were secured gradually and in effect at least were secured by continued selection, by the piling up of variation upon variation. Corn is largely open-pollinated.

In 1900, Johannsen of Copenhagen began working upon a variety of garden beans. He secured pure lines by saving and planting the progeny of individual plants. The beans he worked with were normally self-fertilized. He worked with several pure lines and in each endeavored to change certain characters by continued selection. He followed essentially the method pursued by von Rümker and the Illinois Experiment Station. Johannsen selected particularly for increased and decreased weight, length, and width of seed. His work of selection extended over periods of four or five years, and the results on the whole were negative.

In addition to the work with beans, Johannsen did work with two varieties of barley. In these he selected for defective heads, heads with gaps. His results were negative, as were those with beans. He worked here also with close-pollinated forms.

Slight positive results in one case were offset by similar negative results in another. In one or two instances it would seem that continued selection had some slight positive effect, and longer-continued studies would be of interest.

Johannsen's conclusions seem to be admissible. These are, in effect, that the selection of plus or minus variations does not serve in the least to change the type of the organism. The type is perma-

nently fixed, so far as the selection of extremes in any season is concerned.

Other investigators, working with self-fertilized forms, have secured essentially the same results as were secured by Johannsen. The practical results secured at Svalöf in Sweden strongly confirm the experimental results secured elsewhere.

At first sight there seems to be a striking contrast, between the results secured with the open-pollinated corn and rye, and with the close-pollinated beans, oats, wheat, and barley.

Perhaps the difference is more apparent than real, as may be shown. It has been amply proved that any close-pollinated variety, as purchased on the market, consists of a comparatively large number of closely related forms, which breed true from one year to another. One variety may contain perhaps 100 distinct forms. One of the present-day problems is to determine how minute the differences may be that separate the forms, the "biotypes," as they are called by Johannsen.

Not only are the close-pollinated species composed of many units, but the open-pollinated kinds are similarly formed. Shull has shown that a field of maize is composed of many biotypes or strains.

In the case of close-pollinated forms, a selection from the variety for any particular character will result merely in the more or less complete isolation of the strains or biotypes. No change has been brought about in the variety at all, further than a mere mechanical sifting, so to speak, of the strains already present.

For the present the presumption must be that in naturally open-pollinated forms as well selection has no real productive or creative effect.

We may consider an extreme plus or minus variant, such as high or low protein content in corn, capable of being reached by selection continued over several generations, to have been potentially present before the beginning of selection. A rearrangement of the unit characters may be necessary before the desired end is reached. Perhaps the high protein content is not a unit character in itself, but a result of other characters.

Selection within the open-pollinated organism has more than a mechanical effect, for here the various strains are constantly interworking as the effect of crossing.

We have but little knowledge of how the strains or biotypes act when crossed. The studies of Nilsson-Ehle in wheat and oats show that rather insignificant characters act according to Mendel's law,

and he shows further that two or more, even four units, may be responsible for the production of a single character. He found that the red in wheat kernels may be carried by three units, all Mendelizing, He found apparently four units responsible for the ligula of the oat leaf. Results of this nature almost startle one, and many complications are suggested.

Let us sum up the foregoing presumable statements of fact:

With open-pollinated plants, selection seems to increase or decrease the characters it is applied to, but bounds are soon reached.

With close-pollinated plants, such as wheat and oats, selection seems to be of no value, other than mechanical purification of the variety or race.

All varieties or races of plants are composed of forms or strains that breed true if allowed or compelled to self-fertilize.

When forms or strains are crossed, one with another, the characters of the plants, even the more minute ones, seem to segregate out, or Mendelize.

Many Characters are Complex.—Many characters of plants will be found capable of more complete analysis. Drouth resistance, e.g., depends upon leaf surface, leaf character, various characters of root system, etc. Winter hardiness of alfalfa or wheat is not simple "hardiness," but the hardiness may be traced back to certain physical features.

Winter hardiness has not been analyzed, but it will be in the course of time, and when analyzed we will undoubtedly find (1) that the characters breed true from one generation, (2) that they Mendelize on crossing, (3) that the plant taken from a self-pollinating population which bears all of the characters of hardiness is rare or nonexistent, (4) that by continued crossing and selection a form can finally be obtained that bears all of the "hardiness" characters, and which is the hardiest organism that can be produced until further mutations occur.

In an open-pollinated population, the hardiest plant, or the plant carrying the extreme of any desired character or quality, may be existent in the group if enough individuals are examined.

What, now, are the conditions regarding alfalfa and winter wheat? Briefly these: Alfalfa is an open-pollinated plant. It comes from a semitropical region and naturally is very tender against the cold. Alfalfa strains from South America, Arabia, and Algeria, when brought to the north and subjected to cold weather, kill out entirely, almost without exception. But in spite of this fact we find that alfalfa has

increased in hardiness during its sojourn in this country, until at the present time its "mode" representing hardiness is evidently considerably in advance of the most extreme variant of the original population. Within the memory of living man there has been an absolute increase of hardiness within the race, this without regard to those alfalfas containing the blood of *Medicago falcata*. But the results with the variegated alfalfas are doubtless strictly comparable. How do the results with alfalfa compare with those of winter wheat, which is a close-pollinated form?

Wheat is naturally a biennial, without doubt, and it has become a spring form through breeding, a transition easily accomplished. But for thousands of years it has been fighting its way to the northward with discouraging results. The northward advance of wheat culture in this country has been due more to the proper culture of the crop than to any increase of hardiness. An exception to this may be noted in the introduction of winter wheat from Europe. The Turkey Red is an example of this. Winter wheat has been tried in North Dakota for twenty years, and there has been no appreciable increase in hardiness within that time.

What would have been the result regarding hardiness were wheat an open-pollinated plant? It is of course impossible to answer this question with certainty, but if the hypothesis we are developing is reasonably correct then the winter wheat history would largely be a repetition of the history of alfalfa in the increase of hardiness.

The case of winter rye might be cited. Here, as stated, we have a largely open-pollinated plant and we also have a plant remarkably hardier than winter wheat. This may be of course a mere coincidence.

Now how might the increased hardiness of winter wheat be brought about if the plant were suddenly to be changed from a close to an open-pollinated organism? By crossing and by a consequent segregation and rearrangement of various characters already existing, hardiness might be increased within the limits made possible by the physical elements already present. For instance, the totally prostrate habit of the young plant of one line could be united, say, with the tougher cell wall structure of another line—giving merely a hypothetical case. By the means indicated, a result would be obtained comparable to those obtained in corn breeding. There is scarcely a doubt that an advance in hardiness could be made in this manner.

With alfalfa it is evident that a greater change has been brought about than that just indicated. In other words, the alfalfa plant has

acquired hardiness by acquiring mutations favorable to hardiness. The alfalfa plant has mutated positively towards hardiness.

A natural question is, Will winter wheat mutate in the same manner? We have no means of knowing, without extensive and careful experimental work.

As to methods, there are two possible solutions. As previously stated, the wheat plant is normally self-pollinated. It is not impossible to conceive that there may be variability even in this regard. A certain line or strain of any wheat variety may be more or less open-pollinated. The increased open-pollination might be brought about by an increased length of filaments, by some peculiar attachment of the anther to the filament, or for other morphological or physiological reasons. Having such a line, if such exist, progress within it would doubtless be more rapid than with the ordinary line.

It might be impossible to select a mutating line like the above. In such a case it would be necessary to produce, by abundant crossing, a condition simulating open-pollination. Whether this is possible in a measure sufficient to produce results has probably yet to be tested.

In the determination of winter hardiness, the winters themselves would be the selective agent, and any unfit strain would be promptly eliminated.

In the discussion concerning alfalfa, it was tacitly assumed that mutations had been produced more or less regularly within a comparatively recent period. This fact can only be gotten at deductively, but the evidence is fairly satisfactory. It may be that mutations in alfalfa are more rapidly brought about than in other plants, or, again, perhaps extreme cold, acting upon open-pollinated plants, has a somewhat stimulating influence in regard to the production of mutations. There are cases on record where something of this sort seems to have happened. For the present at least, such statements are mere speculations, but they may be of enough value to record.

The winter wheat in common with other plants is liable to mutations, of course, and some of them may be along the lines of increased hardiness. The rather common appearance of new forms in the winter wheat fields of northern Europe is of interest, though it is apparent that they are due largely to accidental cross-pollination.

VARIATION AND CORRELATION IN WHEAT

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One of the chief difficulties in the way of the improvement of the yield of the smaller cereal grains by selection lies in our lack of knowledge of the exact degree of relationship of the external factors to the performance of the plant, as distinguished from the internal hereditary forces in play. The apparent ease with which "corn improvement" has been accomplished by selection toward uniformity in certain characters has led to the assumption that similar methods can be applied to wheat. Corn, however, is easily reducible to a relatively limited heterozygous condition with respect to a number of desired characters, on account of the large size of the organs upon which selection has to work and the consequent ease with which choice can be exercised. In fact, the assumed success of selection in this case is really the direct consequence of this multiplex heterozygous condition of the average field of corn today, however it may have been primarily. With wheat the question of possible improvement through selection has none of this open simplicity. The wheat plant, being normally and indeed almost inevitably self-fertilizing, and being in consequence, as an organism, in a state of more stable equilibrium with respect to its assemblage of characters, offers fewer salient morphological points to be seized upon, which bear upon the improvement of yield. In corn there are races with as few as eight and others with as many as twenty-four rows of kernels to the ear, races with broad or narrow, shallow or deep kernels; with long or with short ears; races that mature in fifty days; and races that require five to seven months for their development. All of these various clans[a] of corn have been isolated chiefly by farmers through selection, and while, as Shull has shown, any such clan is an extremely complex congeries of characters, yet we recognize these clans as being quite definite, and as possessing ear characters isolated by selection, which have been shown in at least some cases to have an important relation to the yield of grain.

In the *vulgare* wheats there are also morphological types sufficiently well known and perfectly constant. Sherriff's Square-head, White Victoria, Jones' Winter Fife, Dawson's Golden Chaff, Fultz, Turkey, all are names which call up distinct images with respect to their

[a] The word "clan" is used to describe a group of closely related individuals, larger than a family, but not necessarily descended from a single ancestor.

character combinations. But what relation has any of these visible characters to the matter of yield? Aside from the formation of new heterozygote conditions by crossing, some of the derivatives of which will be stable, is there any sure method for the improvement of the wheat plant in respect to yield? In a field of wheat of any existing type taken as it stands, are there individuals of markedly superior yield but indistinguishable from the mass in respect to their morphological characters? Are there discontinuous variations that consistently bear more kernels on the spikelets, more spikelets to the head, and produce more heads to the stool than the other members of their clan? If so, how can they be discovered? We are all perfectly familiar with the fact that any given clan of a wheat race—Turkey, let us say—may under one set of climatic, soil, and cultural conditions yield fifteen bushels to the acre, while with the same soil and climate but under different cultural treatment the yield may be fifty bushels. What can the breeder accomplish in comparison? Is it likely that such a clan may harbor one or more individuals which if isolated might become the progenitor of a family that would yield, side by side with the rest of the population, surely and inevitably within a range of 30 to 65 bushels instead of within a range of from 15 to 50?

The most extensive and notable effort to achieve the isolation of such a family of wheat is undoubtedly that of Hays in Minnesota, the results of which are too well known to need recapitulation here. The tremendous nature of the task and the laborious years involved in the discovery of Prof. Hays' superior families of wheat of higher yielding power may perhaps account for the experiment not having been attempted elsewhere on such a scale, even after the final success which followed his efforts.

The investigations, with a portion of which this paper has to deal, were undertaken for the purpose of determining, if possible, by biometric methods, the relation between certain morphological characters in wheat and the yield of grain. So far as the writer is aware, no attempt has hitherto been made to determine the variation and correlation of characters in pure lines of wheat. While this paper was preparing, the valuable paper of Clark on "Variation and Correlation in Timothy" has appeared from the Department of Plant Breeding of Cornell University (Bulletin 279, Cornell Experiment Station, July, 1910), and will be referred to later on.

The material for the present investigation was originally obtained in 1906 and 1907 by the isolation of 692 individuals taken from 538 different mass variety cultures of named sorts of wheat from many

sources, and representing *durum*, *compactum*, and *turgidum* races in part, but chiefly *vulgare* types of all of the sorts generally known as "varieties." The original selections were made, so far as could be judged, of representative or typical individuals from each clan, using in each case a single head as the unit of selection. The cultures from these unit selections have been continued up to the present time, although not all of them have been planted each year. Eighteen of these races are now growing in increase plots of from one-tenth to one-half acre each at the Kansas Station; 35 are in one-twentieth acre comparative yield and increase plots; while the remainder are in plots of smaller size. So far as the isolation and propagation of such pure lines or families is concerned, it is a comparatively simple and elementary matter. A comparative yield test of the evidently more promising of these pure strains on one-tenth acre plots will, if carried on for a number of years on the same plots in rotation, undoubtedly afford a comparatively trustworthy criterion for the retention of those which are demonstrated to yield best under as nearly identical conditions as field plots can afford.

Of the original series, all were subjected to biometric study for the years 1906 and 1907, and about twenty-five families have been subjected to a biometric analysis covering about fifty characters in all the individuals of each family, for the two generations, 1907 and 1908, immediately following the year of their original isolation (in all of these cases 1906). Practical reasons prevented the planting of these series in 1909, but all of the 1908 progenies were planted in the fall of 1910, and will be subjected to similar measurements again at maturity.

The present paper deals with biometric studies upon three of these families, Nos. 640, 1122, and 1123, for which the data are now completely reduced. No. 640 is a family derived from a plot of wheat called "Binkel" but not of the type. So far as its more obvious characters are concerned, it is a soft wheat with white, pubescent, beardless heads. Nos. 1122 and 1123 were both derived from a plot of Crimean wheat (U. S. Cereal Introduction No. 1435). No. 1122 is bearded and glabrous, with white glumes. No. 1123 is bearded, also glabrous, with red glumes. Both would be classified as hard wheats. In addition to individual variation curves for the factors above mentioned, frequency curves for culm length and for the number of grains per spike were plotted for each family for 1907 and 1908. The coefficients of variation for the same characters, and also the correlation coefficients, using culm length as subject and spike length and

the number of grains per spike as relatives, respectively, for each of the three families mentioned, for the two sucessive generations of the cultures, were determined.

The scope of this investigation is, then, to ascertain the exact relation of "place variation," in the sense used by Tower, to the morphological characters of wheat, including those that are most intimately related to yield. This seems to be fundamental. For years there have been efforts to "improve" wheat by selection of the so-called "best" heads, or the heaviest heads, or the best-yielding head-rows. from the field. This method is at least as old as Hallett, and is still very commonly practiced in one form or another in Germany and in this country as well, but without having furnished any definitely satisfactory results. In general, it is evident that the selection, year by year, of the supposedly best plant from a row, or of the best head-row of plants in a plot, must be the merest toying with chance, if place variation plays any important part in the manifestation of superior yield by individual plants.

In the first place we generally fail to take into consideration the immensely complex group of activities, organic and inorganic, for which the wheat plant, let us say, is the focus. With wild plants growing in an old plant formation in a long-established flora these factors must be far less variable from year to year. A physically undisturbed soil except for animal and insect movements, a close and well-balanced competition for the water supply, and a presumably stable condition of the bacterial flora would all tend to reduce the range of the so-called place variation. In a wheat field, on the contrary, we have had in most of our agricultural regions a long-continued physical disturbance of the soil, with resultant changes in fertility, brought about by changes induced in the soil solutes and by the more intensive development of soil bacteria. Not only that, but the amount and degree of all of these factors must vary immensely from year to year with different kinds and methods of treatment of the soil, and under different rotation systems or lack of system. I doubt whether there are many American experiment stations in which the soil conditions in the experimental wheat plots have been brought to anything like a state of stable equilibrium. Under field conditions as we generally have them, the reliability of yield tests on small plots may be called into very serious question, in most cases, on account of varying conditions of soil in closely adjoining areas in the same plot. Various methods have been devised for offsetting these disturbing factors, which need not be discussed here.

So far as the present investigation is concerned, every effort was made to secure uniformity of field conditions. The grains were planted 2 inches apart in 66-foot (1 chain) rows, the rows being 8 inches apart. The plots were therefore not large enough, apparently, to admit of great variation in the nature of the field. As much individual development of the plants as possible was obtained by the uniform spacing of the plants in the rows. A distancing of the plants by more than 2 inches in the row was considered undesirable on account of the greater exposure of the soil and consequent danger of loss of stand.

At harvest time each plant was removed from the soil separately, and all the individual descendants of each single plant of the year before were bound up together and taken into the laboratory, where they were subjected to a careful series of measurements by a trained force of assistants. Each stalk, with its characters of culm, spike, and kernel, was recorded on a culm sheet; all of the culm sheets for a plant being summarized by averaging to make a plant summary sheet. On account of the smaller number of individual plants in the 1907 generation, the constants for that year are computed from the individual culm records of that year, so that for the year 1907 "n" (the number of the variates) means the number of *culms*, whereas for the year 1908 "n" stands for an aggregation of culm records; in other words, for the number of individual *plants*, obtained by averaging the culm records, plant by plant. In addition to the variation and correlation data referred to, another series of computations was made, in which all of the plants (834), of 25 pure lines for the year 1908 were taken as variates, and the correlation coefficient determined between the number of culms per plant taken as subject, and the length of culm, number of grains per spike, and the weight of grain per spike taken as relatives, respectively. The coefficients of variation and the frequency distributions for the same factors were also determined.

The purpose of this phase of the investigation was to ascertain the probable relation between the stooling capacity of the wheat plant and its yield.

RESULTS

While the data herein presented cover only three strains for two years, the fact that they have been conducted with pure lines exclusively, and give results that are perfectly harmonious among themselves so far as they go, seems to justify their presentation in advance of the data for the entire twenty-five families investigated and without waiting for another year's results. While this paper was in progress the recent

paper of Clark, from the Laboratory of Experimental Plant Breeding of Cornell University, on "Variation and Correlation in Timothy," already referred to, has appeared, which raises interesting suggestions. The work of Clark deals with a perennial plant. The same individuals having been *in situ* in the field for three successive generations, occupying the ground for the entire period undisturbed and under identical cultural conditions, the problem of place variation is presented with a minimum of variables.

With an annual plant like wheat, where the field must be changed each season to preclude the invasion of volunteers into a field of pure cultures, the problem of place variation is a double one, involving at one and the same time a year-to-year and a place-to-place variation. On the other hand the accomplishment of a wheat plant is the accomplishment of a single season alone, so far as vegetative growth and yield are concerned. In timothy, however, and in all perennials which store up food in underground parts, there is the possible variable, due to the carrying over of a food supply in the underground parts from a favorable to an unfavorable season, and a consequent performance in the aërial parts during the second season that may be a partial residuum of the preceding season's activities. Data for herbaceous perennial grasses with like underground systems may of course reasonably remain comparable.

Despite the fact that the growing season, March–July of 1908, was far more favorable in respect to rainfall, there was a uniform decrease of variability in culm length, spike length, and in the number of grains per spike, as expressed by the coefficient of variability. Tables 12, 13, 14 and 15 indicate the percentage decrease in the coefficient of variability for the year 1908 as compared with 1907.

Summarizing the data here they are—

Percentage decrease from 1907 to 1908.

	Per cent.
Culm length	51.0
Spike length	32.7
Number of grains per spike	42.1
Total average	41.9

From the above data it is clear that there is more than a coincidence in the facts shown. A uniform absolute and percentage decrease in respect to all the determinations for each factor considered must necessarily depend upon some fundamental causes.

The field plots were located during each season on a uniform tract

of upland clay loam, and in different portions of the same five-acre field. It would not seem likely, therefore, that fundamental differences in soil would come into play in this case. The mode of planting and the distancing of the plants having been alike for the two years, it is hardly possible that differences in performance could have been ascribed to differences in root and leaf space in the field. Vacancies occurred in both years caused by failure of seeds to germinate and by the occasional destruction of individuals later. What this amounted to cannot be stated. Such occurrences are, however, of a scattering and occasional nature and would not combine to produce a uniform effect from one year to the next.

The climatic factors remain to be considered. Whether or not the uniform decrease in variability under consideration can be ascribed to the climatic conditions alone or not, is of course a question. To assert it as a probable affirmative would certainly be the simplest apparent solution. One would have expected perhaps, with the increased rainfall of 1908, and better growing conditions in consequence, that increased variability in all the organs would have followed as a result. There is at least some ground for this general view. The contrary, however, occurred. There remains the possible explanation that the more unfavorable year of 1907, with its lesser rainfall during the spring growing period, held back the weaker plants to such an extent as to produce a net effect in biometric terms, of greater "variation" in the characters of culm and spike length, and brought about a straggling condition of seed production among the various plants that would likewise be interpreted biometrically as being a higher "variability." Inasmuch as the cultures of 1907 and 1908 were not grown with the problem of place variation in mind at the time, a statement cannot be given that goes behind the biometric data. The unfavorable season showed itself in the shriveled character of the seed produced in 1907—uniformly over all the plots. The season of 1908, on the other hand, was normal. The plants all having had ample opportunity to develop, slight initial handicaps were easily overcome, the stand was uniform, and the plants more nearly alike. In other words, biometrically speaking, they were less "variable" among themselves than in 1907. Now it is just this obliteration of differences in a good year that renders selection within a strain a difficult matter in wheat. The differences to be selected for among individual plants in such a pure strain are so slight, often indeed requiring biometric methods to bring them out, that in an ordinary good season field selection of superior individuals that

are such permanently, *because of hereditary tendencies*, and not temporarily, on account of environmental stimuli, is an exceedingly difficult matter. It is assumed that here as elsewhere, selection—continuous selection—within even a "pure line," may have its effect in shifting the mode of the characters selected for and in producing a superior race within the strain, so long at least as the selection is practiced.

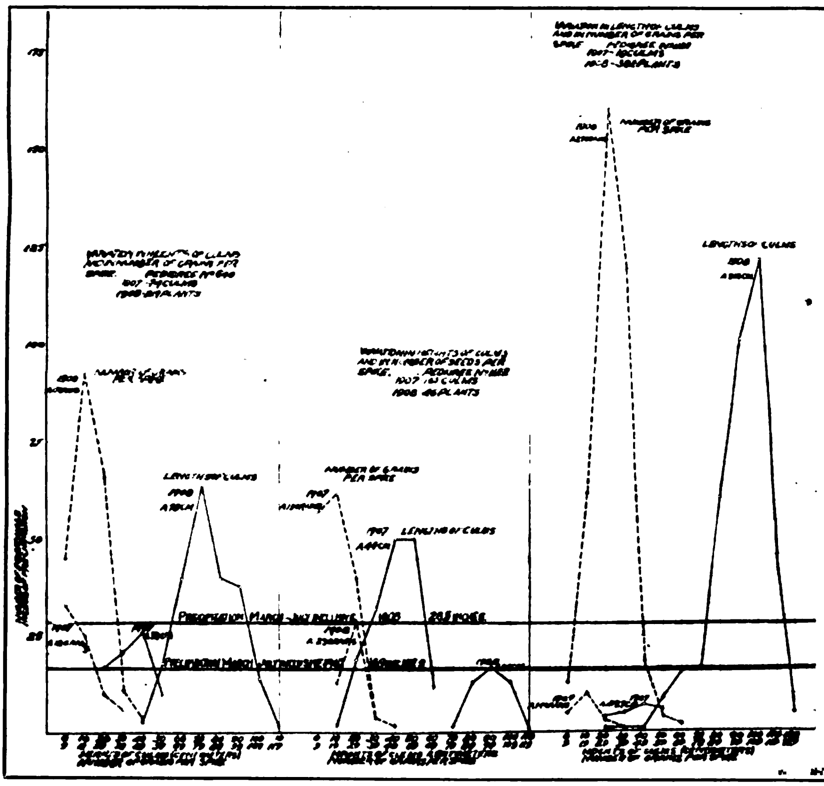

FIG. 1. Frequency polygons for culm length and number of grains per spike in No's. 640, 1122 and 1123, showing shifting of the modes in both characters from 1907 to 1908.

In Figure 1 frequency polygons for Nos. 640, 1122 and 1123, plotted for the two years 1907 and 1908 for the characters of culm length (solid line) and number of grains per spike (dotted line), are shown.

In the case of each character and for each strain there is seen to be a positive shifting of the mode and of the mean. The data are best reviewed in tabular form as follows:

TABLE 1—*Shifting of the mode and of the mean, 1907 and 1908.*

Pedigree No.	Height of culms.				Number of grains per spike.			
	Mode (class).		Mean.		Mode (class).		Mean.	
	1907.	1908.	1907.	1908.	1907.	1908.	1907.	1908.
			Centimeters.	*Centimeters.*			*Grains.*	*Grains.*
640	40–49	70–79	38	78	0–9	10–19	12	17
1122	40–59	90–99	44	94	10–19	20–29	13	23
1123	40–49	103–109	39.7	95.6	10–19	20–29	14	27

The actual and percentage positive shifting of the mean in the case of both culm length and of the number of grains per spike is shown in the following table:

TABLE 2—*Increase in mean for 1908 over 1907.*

Pedigree No.	Height of culm.		Number of grains per spike.	
	Absolute increase.	Percentage increase.	Absolute increase.	Percentage increase.
	Centimeters.		*Grains.*	
640	40	51	5	30
1122	50	53	10	43
1123	55.9	58	13	48
Average......	....	54	....	40

Table 2 is interesting in that it shows clearly that while there was a shifting of the mean in both cases in the same direction, due to the better seasonal conditions of 1908 over those of 1907, yet the percentage change differs somewhat markedly in the different strains. These percentage differences might naturally be suspected to be chargeable to the characters of the different races as such. Whether this is so or not will be considered later on. Now since no intra-strain selections were made in 1908, but the whole of the seed of each race of 1907 was sown without discrimination, it follows that the general shifting of the mean and mode in 1908 in the positive direction was a seasonal phenomenon pure and simple—in other words, a case of place-variation. Reference to the field book of 1908 shows that No. 1123, which effected the greatest percentage advance as shown by Table 2 in the positive shifting of its mode and mean for both culm height and seed production, was actually the poorest yielder of the three for the year 1908. As a matter of fact the row yield of No. 1122 was nearly twice that of 1123 and nearly three times that of No. 640.

The data for changes in the mode and mean of spike length, although not shown graphically, are given in tabular form as follows:

TABLE 3—*Changes in mode and mean, 1907 and 1908.*

Pedigree No.	Spike length.			
	Mode.		Mean.	
	1907.	1908.	1907.	1908.
	Centimeters.	*Centimeters.*		
640	7.0	....	7.0	....
640a	....	9.2	....	8.7
1122	8.5	10.0	8.4	10.2
1123	4.5	7.5	5.7	7.7

TABLE 4—*Increase in mode and mean for 1908 over 1907.*

Pedigree No.	Spike length.			
	Mode.		Mean.	
	Absolute increase.	Percentage increase.	Absolute increase.	Percentage increase.
640	2.2	24	1.7	19.5
1122	1.5	15	1.8	17.6
1123	3.0	40	2.0	26.0
Average......	....	....	....	21

From Tables 3 and 4 it is seen that there was an increase, both absolute and percentage, in mean and mode of spike length as well as in the case of the other two characters.

What is responsible for the practically uniform positive shifting of the mean and of the mode in the case of culm length, spike length, and the number of grains per spike? Inspection of the weather records (figs. 2 and 3), for the spring months of the two years 1907 and 1908, and especially of the rainfall data, furnishes the natural explanation for the fact of change, but does not explain the reason for the relative differences in degree of change.

In searching for a reason for these differences in the *relative changes* in the percentage increase, the first suggestion, as previously stated, would naturally be that they were due to racial differences in the strains themselves. Here, however, is the precise point where the biometric data, unsupported by a knowledge of field conditions, would be liable to lead to wrong inferences. Figures 4, 5, and 6

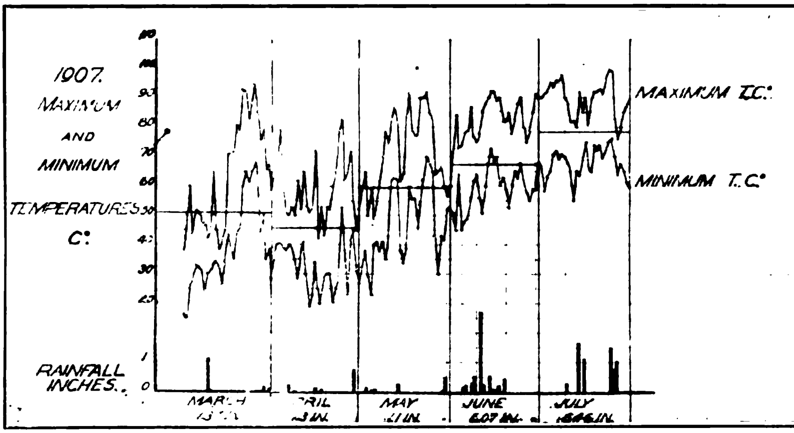

FIG. 2. RAINFALL AND MAXIMUM AND MINIMUM TEMPERATURES. 1907.

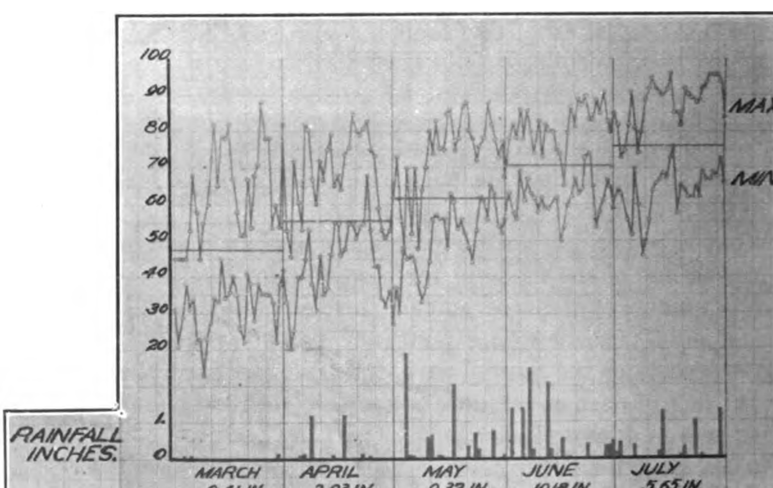

FIG. 3. RAINFALL AND MAXIMUM AND MINIMUM TEMPERATURES. 1908.

give a graphic plotting of the yield-per-row of all the different strains and their controls that were planted in the same blocks with the strains under present discussion.

The location of the pedigree races was as follows:

No.	Block	Plot.
1123	III	1
1122	II	6
640	I	1

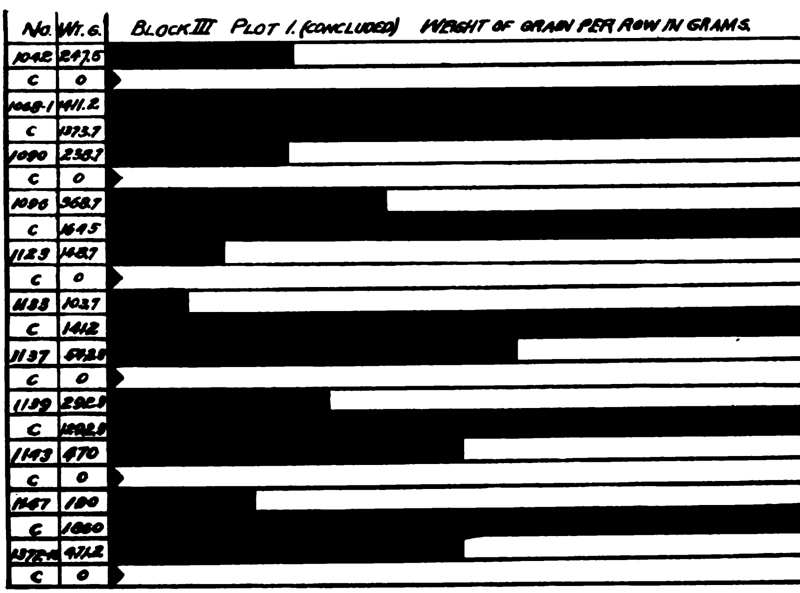

FIG. 4. Graphic plotting of yield in grams, of rows of pure bred wheats and their controls, (marked C) in Block III, Plot I, of the experimental field. No. 1123 is in the center of the block. The control rows (pointed graphs) were all destroped in this block.

The three strains in question were therefore located in separate blocks, in subdivisions in two cases at least of different larger plots within the same five-acre field. Taking the check or control rows (of Kharkov wheat) as a gauge or criterion of what we may call the normal yield-expectancy for each block for the season in question (1908), it will be seen at a glance from the diagrams that if the expectancy of yield-per-row for the three blocks be judged by the mean performance (row-yield of grain in grams) of the control rows, then they stand in the following order from the highest to the lowest:

No.	Block.	Plot.	Yield expectancy.	
1123	III	1	1465 grams	Fig. 4
1122	II	6	536 grams	Fig. 5
640	I	1	320 grams	Fig. 6

In Block III (fig. 4), although six control rows were destroyed by accident, it is apparent at once that the normal performance of that block is represented by the remaining control rows, and by one or two of the pedigree strains, and amounts to about 1500 grams per row. Comparison with figures 5 and 6 shows that if the average conditions

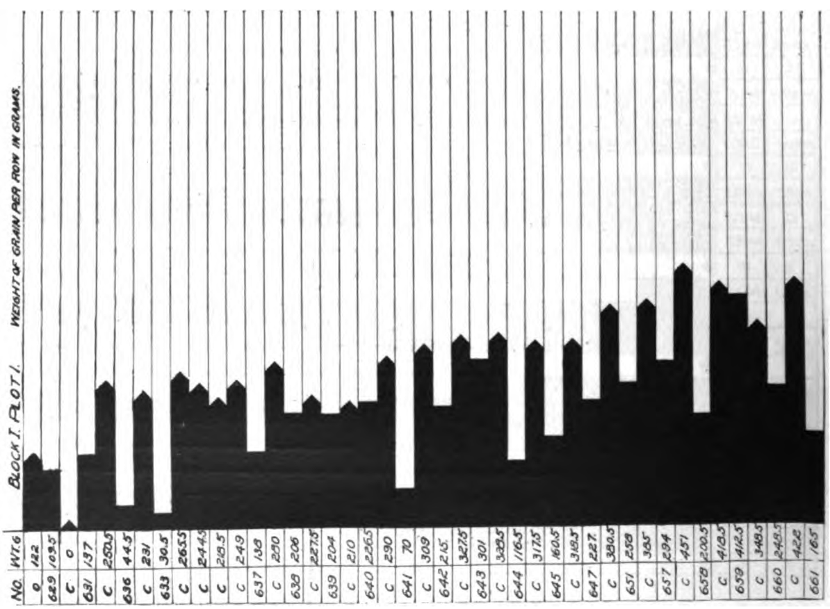

FIG. 5. Graphic plotting of yield in grams, of rows of pure-bred wheats and their controls, (marked C) in Block II. Plot 6, of the experimental field. No. 1122 is in the center of the block. The control rows are indicated by the pointed graphs.

in these three blocks in the field are fairly represented by the control rows of Kharkov wheat, then 1123 was in the best, 1122 in the next best, and 640 in the poorest yielding block, respectively.

Referring to the pedigree strains themselves it will be seen that No. 640 in Block I came fairly well up toward the mean yield-expectancy[b] of its block, with a row-yield of 226.5 grams—not equalling the mean of the controls, but approximately well toward it. No. 1122, with a row-yield of 468 grams, arrived more nearly at the yield-expectancy

[b] By "yield-expectancy," is meant the normal grams-per-row yield as determined by the controls.

of Block II. Its yield, in other words, was normal for the block in question. No. 1123 however, with a row-yield of only 128.7 grams, was far behind the yield-expectancy of Block II as judged by the controls. The inference is inevitable that No. 1123, if it had been grown in Block I with No. 640, and with the lower yield-expectancy of that block, would have been nearly or quite obliterated. It was the aggregation of the superior local conditions alone in Block III that saved it. Turning again to the data in Tables 1 and 2, it is seen that if we compare the rank of the three pedigree strains as determined

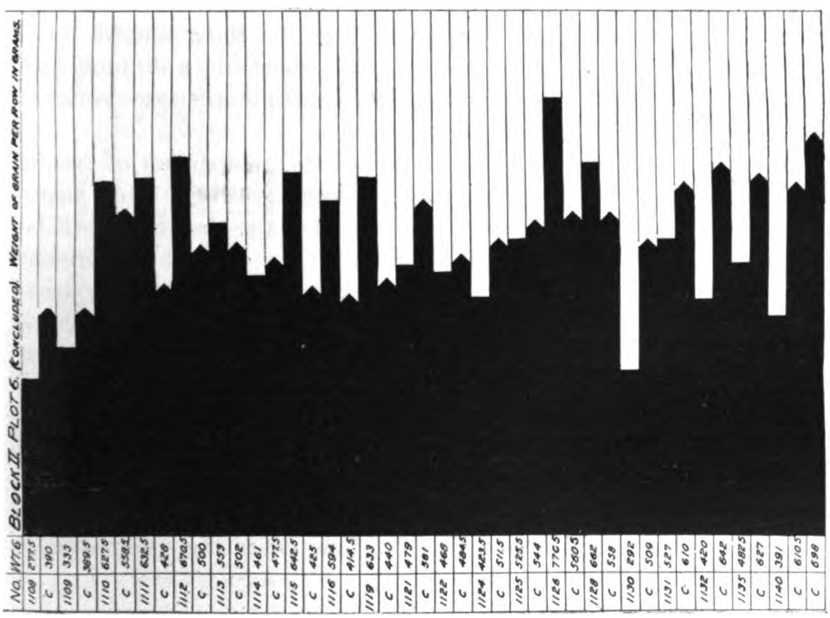

Fig. 6. Graphic plotting of yield in grams, of rows of pure bred wheats and their controls (marked C) in Block I, Plot I, of the experimental field. No. 640 is toward the center of the block. The control rows are indicated by the pointed graphs.

by the degree of positive shifting from 1907 to 1908, of the means and modes of culm length, and of the number of grains per spike, we find that this is precisely the order of the yield-expectancy of the blocks of land on which the strains were grown in 1908.

It appears probable, therefore, that the percentage increase of shifting of the means and modes of performance in the case of cultivated plants from one season to the next is not necessarily a measure of the relative superiority or inferiority of the races under experiment at all.

It is most probably a function of the soil in which the strains are growing. It is perfectly evident from the cases in hand that the upward shifting in the case of 1123, for example, is no measure of its inherent native superiority as a race, but is due solely to the upward drag of the soil conditions of the plot of ground in which it grew This was sufficient to shift the mode and mean of performance in the characters referred to (fundamental ones from the practical standpoint)—much farther than these were shifted in the case of Nos. 640 and 1122. That the situation might have been reversed had No. 1123 been grown in the same block with No. 640 is self-evident.

From the whole matter it is plain that the thing sought for—individual superiority in a pure strain of wheat—is a difficult fact to determine, short of growing the same strains on the same series of plots for a considerable number of seasons.

No conclusions can be arrived at from the comparison of results with pedigree strains covering but a few seasons' growing. How many seasons will be necessary to define the range of the place factor will be a matter of experiment in each instance. The data in the present case demonstrate sufficiently the utter necessity of determining accurately the part played by place-variation in the performance of cultivated plants before coming to conclusions as to the superiority of strains. In the races under experiment, no selection was practiced within any of the strains, the whole quantity of the seed of 1907 having been sown in 1908. Where selection is practiced, the whole affair becomes immensely more complicated. Unfortunately it is all too customary to ascribe to the effect of selection an increased efficiency of performance, which is in the main a function of the summation of factors called place-variation.

CORRELATION

The correlation coefficient was determined between culm length in centimeters as subject, and spike length in centimeters as relative, and likewise between culm length and number of grains per spike. Tables 5 and 6 give the chief constants as determined for each of the races Nos. 640, 1122, and 1123 for the years 1907 and 1908. An inspection of Table 5 shows that there was an increase in r for No. 640 and a decided decrease in r for Nos. 1122 and 1123, the latter even showing negative correlation for 1908. In the case of No. 1123, however, the small number of culms available in 1907 precludes any definite conclusions from the data for that year. It is evident nevertheless, that there is considerable correlation between the growth of

TABLE 5.—*Correlation between culm length in centimeters, subject, (Y) and spike length in centimeters relative (X).*

Constants.	640 (1907).	640a (1908).	1122 (1907).	1122 (1908).	1123 (1907).	1123 (1908).	Average. 1907.	Average. 1908.	Differences, absolute +	Differences, absolute −	Differences, percentage +	Differences, percentage −
M., Y	39.5	84.5	49.5	94.5	44.5	94.5	44.5	91.1	46.6		51%	
M., X	7.0	9.2	8.5	10.0	4.5	7.5	6.6	8.9	2.3		26	
A., Y	35.6 cm.	83.0 cm.	44.0 cm.	94.0 cm.	40.0 cm.	94.0 cm.	39.8	90.3	50.5		56	
E.A., Y	±0.1666	±0.4372	±1.9695	±1.8383	±1.6279	±0.9071	±1.2546	±0.7275				
A., X	7.0 cm.	8.7 cm.	8.4 cm.	10.2 cm.	5.7 cm.	7.7 cm.	7.0	8.8	1.8		20	
E., A., X	±0.1268	±0.0564	±0.2883	±0.1372	±0.1796	±0.0747	±0.1982	±0.0902				
σ., Y	11.48 cm.	14.47 cm.	11.68 cm.	8.43 cm.	11.06 cm.	10.59 cm.	11.40	11.16		0.2400		2 0
E., σ., Y	±0.5421	±0.3092	±1.3926	±0.5928	±1.1510	±0.6414	±1.0285	±0.5144				
σ., X	1.9000 cm.	1.8669 cm.	1.71 cm.	1.38 cm.	1.22 cm.	0.8720	1.6100	1.3721		0.2371		14.7
E., σ., X	±0.0897	±0.0399	±0.2039	±0.0970	±0.1269	±0.0528	±0.1401	±0.0632				
r	.6093	.6792	.6183	.4344	.5646	−.2370	0.5974	0.2922		0.3052		51.0
E., r	±0.0499	±0.0162	±0.0325	±0.8007	±0.1003	±0.0780	±0.0609	±0 0583				
n	102 culms	498 culms	16 culms	46 plants	21 culms	62 plants						

* See Table below.

TABLE 6.—*Correlation between culm length in centimeters, subject, (Y) and number of grains per spike relative, (X).*

Constants	640 (1907).	640a* (1908).	640b* (1908).	1122 (1907).	1122 (1908).	1123 (1907).	1123 (1908).	Average. 1907.	Average. 1908.	Differences, absolute +	Differences, absolute −	Differences, percentage +	Differences, percentage −
M., Y	44.5	84.5	74.5	49.5	94.5	44.5	94.5	46.1	87.0	40.9		47	
M., X	4.5	14.5	14.5	14.5	24.5	14.5	24.5	11.1	22.0	8.4		43	
A., Y	38.0 cm.	83.0 cm.	78.0 cm.	44.0 cm.	90.0 cm.	39.7 cm.	95.6 cm.	40.5 cm.	86.6 cm.	46.1		53	
E., A., Y	±0.7229	±0.4296	±0.6349	±0.6167	±0.0832	±1.6526	±0.5173	±0.9974	±0.4162				
A., X	12 grains	20 grains	17 grains	13 grains	23 grains	14 grains	27.0 grains	13.0 grains	21.7 grains	8.7		40	
E., A., X	±0.7229	±0.2767	±0.4129	±0.4966	±0.0515	±1.1806	±0.3244	±0.8000	±0.2663				
σ., Y	9.22 c,m	14.47 cm.	13.93 cm.	11.71 cm.	8.37 cm.	10.68 cm.	14.99 cm.	10.53 cm.	12.94 cm.	2.41		18	
E., σ., Y	±0.5111	±0.3038	±0.4489	±0.4361 cm.	±0.0588	±1.1685	±0.3642	±0.7052	±0.2939				
σ., X	9.22 grains	9.32 grains	9.06 grains	9.43 grains	5.18 grains	7.63 grains	9.40 grains	8.76 grains	8.24 grains		0.52		5.9
E., σ., X	±0.5111	±0.1956	±0.2919	±0.3511	±0.0364	±0.8835	±0.2294	±0.5819	±0.1883				
r	.6597	.7615	.7517	.7888	.6287	.5512	.5317	0.6665	0.6684	0.0019		0.3	
E., r	±0.0443	±0.0124	±0.0198	±0.0199	±.0601	±0.1077	±0.0247	±0.0573	±0.2920				
n	74 culms	516 culms	219 culms	164 culms	46 plants	19 culms	382 culms						

* No 640 for 1908 was divided into two groups. For 640a, were taken those plants only that bore ten or more culms per plant. For 640b, were taken those plants alone that bore less than ten culms per plant.

the two regions of culm and spike in the wheat plant, and that taller plants will generally produce longer heads. This fact would probably have appeared more clearly in the data for 1908, except for the fact that the means of culm length and of spike length for each plant were taken, instead of the individual culms, *seriatim*. This was done to shorten the calculations. So far as the correlation between culm length and the number of grains per spike is concerned (Table 6), there was a decrease in r in the case of Nos. 1122 and 1123 and an increase in the case of 640. Attached to each of the tables is given the average for each important constant for all the races and for the two years, together with the absolute and percentage increase or decrease respectively of those constants. It will be seen that the whole material shows a positive shifting of the modes and the means of both the correlatives. It is interesting to note that in both correlations there is positive shifting of r for No. 640 and a negative shifting of r for Nos. 1122 and 1123. The instability shown in the degree of correlation between culm length on the one hand and spike length and the number of grains per spike on the other suggests that here are growth correlations dependent very strongly on place and seasonal conditions.

With a view to determine whether or not there was a closer correlation between vegetative growth and productivity in wheat where the number of culms was large than where there were few culms per plant, the raw data for No. 640 for 1908 were grouped into two classes. The one class, marked 640a, included all the progeny plants of No. 640 in 1908 that bore ten or more culms per plant; the class marked 640b comprised all those plants of No. 640 in 1908 that bore less than ten culms per plant.

From Table 6 a comparison can be made of the constants for these two classes. In the correlation between culm length and number of grains per spike, it will be seen that r has a higher value (0.7615) in 640a than in 640b (0.6597). It will be noted that the mean of culm length (83 cm.) is higher in the former than in the latter (78 cm.). Moreover the absolute variability, as expressed by the standard deviation, is less for both the correlatives, $\sigma Y = 14.47$ cm.; $\sigma X = 9.32$ grains) in 640a than in 640b ($\sigma Y = 13.93$ cm.; $\sigma X = 9.06$ grains). In relative variability, however, as expressed by the coefficient of variability (Table 10), 640b is but slightly more variable than 640a (17.43 as compared with 17.85), so far as culm length is concerned. For number of grains per spike, C. V. 640a, is less than C. V. 640b (46.60 as compared with 53.29).

The conclusion from the correlation data for these two classes is

that there is a marked general tendency for the taller growing plants to bear more seeds per spike, and that this tendency is relatively more marked in the case of plants that produce a large number of culms per plant than with plants that produce few. Whether this correlation is a fact that bears on selection or is simply a general expression of vigor in all strains, remains to be worked out from further data.

The calculation of percentages of increase or decrease places all the constants in a position to be compared directly with one another. Taking the data from the two tables, 5 and 6, the increase and decrease respectively of the various constants for 1908 as compared with 1907 falls into the following order:

TABLE 7.—*Constants increasing from 1907 to 1908.*

Rank.	Constant.	Per cent increase.	
1	Mean of culm length (1st determination) Table 9	56	54.5
2	Mean of culm length (2nd determination) Table 10	53	
3	Mode of culm length (2nd determination) Table 9	51	
4	Mode of culm length (2nd determination) Table 10	47	49.0
5	Mode of number of grains per spike	43	
6	Mean of number of grains per spike	40	
7	Mode of number of spike length	26	
8	Mean of number of spike length	20	
9	σ culm length 2nd determination	18	
10	r culm length (subj.) no. grains per spike (rel.)	0.3	

TABLE 8.—*Constants decreasing from 1907 to 1908.*

Rank.	Constant.	Per cent decrease.
1	r culm length-spike length	51.0
2	σ spike length	14.7
3	σ No. grains per spike	5.9
4	σ culm length (1st determination)	2.0

In addition to the determination of r in the cases given, the correlation was determined in the case of a population comprising twenty-five pure strains of *vulgare* wheat taken together, between the number of culms per plant on the one hand and culm length, number of grains per spike, and weight of grain per spike, respectively, on the other.

The purpose of this computation was to determine the relation between the stooling or tillering capacity of the wheat plant and its vegetative growth and productivity. It is evident that there is high correlation here only in respect to the relation between stooling capacity and the weight of grain per spike.

TABLE 9.—*Correlation between number of culms per plant and culm length. grains per spike and weight of grain per spike.*

Constants.	Culm length (cm.) relative (X).	Number of grains per spike, relative (X).	Weight of grain per spike (g.), relative (X).
M., *Y*..........	3 culms per plant	2 culms per plant	2 culms per plant
M., *X*..........	74.5 cm.	27 grains per spike	1 gram per spike
A., *Y*..........	7 culms per plant	6.9 culms per plant	6.9 culms per plant
E., A., *Y*.......	±0.1220	±0.01162	±0.1196
A., *X*..........	80 cm.	22.2 grains per spike	2.96 grams per spike
E., A., *X*.......	±0.3499	±0.2376	±0.6958
σ., *Y*..........	5.1267 culms per plant	4.9776 culms per plant	5.0965 culms per plant
E., σ., *Y*........	±0.0848	±0.0822	±0.0846
σ., *X*..........	14.7026 cm.	10.1768 grains per spike	2.9652 grams per spike
E., σ., *X*........	±0.2434	±0.1680	±0.0492
r................	0.2810	0.1805	0.8345
E., *r*............	±0.0219	±0.0225	±0.0712
n...............	803 plants	834 plants	826 plants

NOTE:—Number of culms per plant subject, Y.

It is clear that whatever promotes tillering immensely promotes the weight of grain per spike, but only in an enormously lesser degree the number of grains per spike. If a practical inference may be drawn from this, it is that the excessive sowing of seed wheat often practiced, and which fills the ground with so many plants that much tillering is impossible, actually lowers the yield effectively through lowering the grain-weight per spike, which is closely correlated with the tillering habit.

It is interesting to note that where, as in the present case, plants are grown in rows 8 inches apart and 2 inches apart in the row, the greatest number of individuals is grouped around the class of from 2 to 3 culms per plant, while the mean or average is 7 culms per plant. It also appears that in a wheat population as a whole, composed of diverse races of *vulgare* wheats, grown under the same conditions as above stated, the mean seed production is 22 grains per spike, and the mean weight of grain per spike approximately 3 grams. This of course is for one year (1908), but may be taken as a fair index to the probable performance for a good season.

In the matter of the relation between the number of culms per plant on the one hand—in other words, the amount of stooling of the plant —and culm length, number of grains, and weight of grain per spike on the other, the data from the correlation tables receive a fuller interpretation when taken in connection with the frequency polygons.

Taking the number of culms per plant in classes having a class-range of 10 as abscissae, and the weight of grain per spike and height

of culms respectively as ordinates, we have the polygons shown in figs. 7, 8, and 9.

In figure 7 it is clear that the increase in the weight of grain per spike continues indefinitely with the increase in the tillering habit;

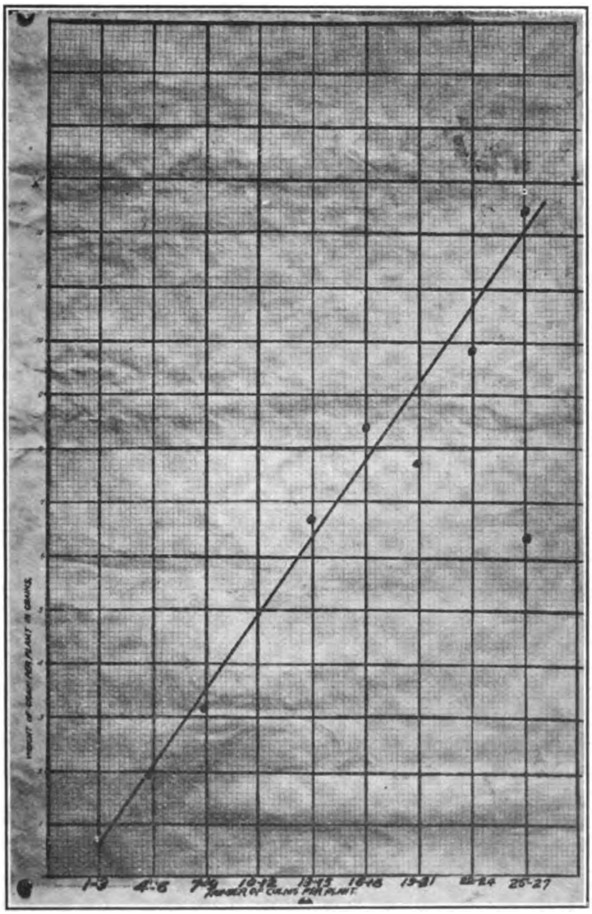

FIG. 7. Graph showing the relation between the number of culms per plant, (abscissae), and the weight of grain per spike (ordinates), in a population consisting of 25 pure lines of wheat.

and its rate of increase is sharp. This brings out the significance of the facts expressed by the high correlation coefficient, 0.8345, very plainly.

From figure 8 it appears that, although the low correlation coefficient (0.1805) indicates a very slight interrelation of the two phenomena of number of culms per plant and the number of grains per spike, the curve in figure 7 shows that it is when the class 16 to 18 culms per plant is reached and from there on, that the number of grains per spike begins to undergo a sharp decline, previous to which point whatever correlation there is exists.

Likewise in the curve on figure 9, although the correlation coefficient of 0.2810 indicates again a very slight dependence of height of culm

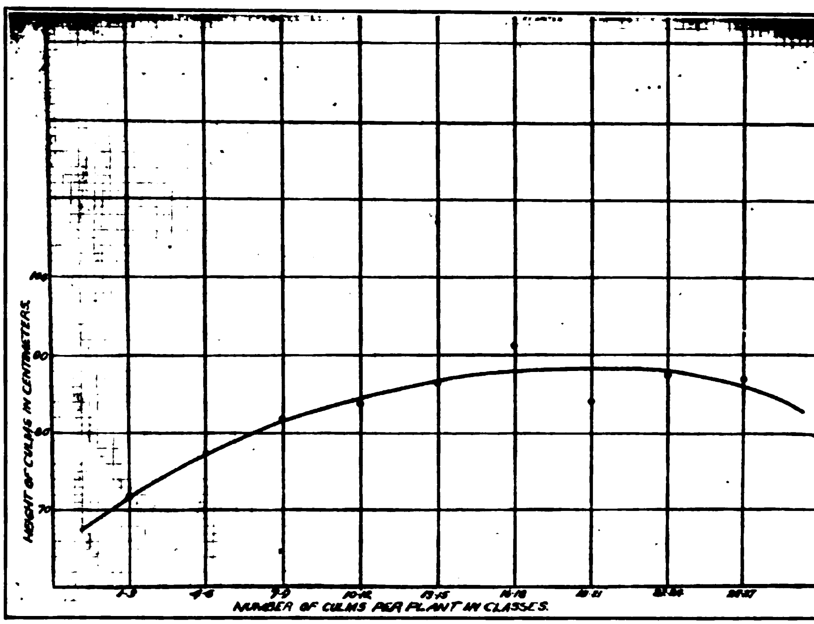

FIG. 8. Graph showing relation between the number of culms per plant, (abscissae), and the number of grains per spike, (ordinates), in a population consisting of 25 pure lines of wheat.

upon the number of culms per plant, the graph demonstrates more clearly the exact nature of that relationship. It appears that, after the 19 to 21 class is passed, the height of culm diminishes slightly with the increasing number of culms, although there has been some correlation up to that point.

The conclusion would be that although the weight of grain per spike increases directly, rapidly, and continuously as the plants stool the more vigorously, there is nevertheless a balance soon arrived at

between the amount of tillering and the number of grains that can be borne per spike, and also the height that can be reached by the culms; excessive stooling being soon followed by decline in both actual seed production per head and in the height of the stalks.

COEFFICIENT OF VARIABILITY

The variation phenomena, so far as represented by this coefficient, have already been discussed in part, especially with respect to the

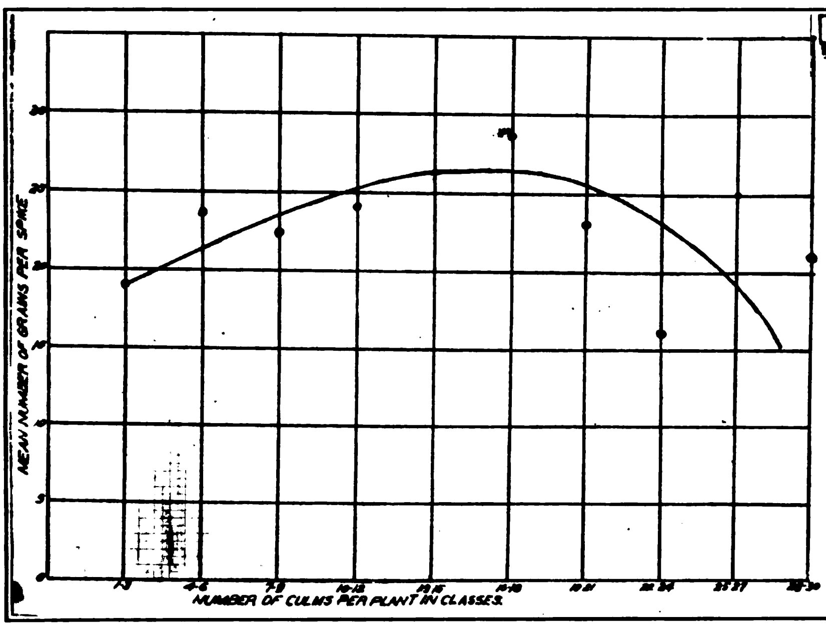

FIG. 9. Graph showing relation existing between the number of culms per plant, (abscissae), and the heights of culms, (ordinates), in a population consisting of 25 pure lines of wheat.

decrease in variability of all the factors considered in all three of the strains from 1907 to 1908. It remains to consider briefly the degree of variation in the different factors.

Following is a complete table giving the coefficient of variability for all the characters under observation.

TABLE 10.—*Coefficient of variability for all the characters under observation.*

Correlation between—		Coefficient of Variability.	Error Coefficient of Variability.
Number of culms per plant, subject, (*Y*)		73.24	±2.4696
Culm length, relative, (*X*)		18.37	±0.3197
Number of culms per plant, subject, (*Y*)		72.13	±1.7015
Number of grains per spike, relative, (*X*)		45.84	±0.9021
Number of culms per plant, subject, (*Y*)		73.85	±1.2255
Weight of grain (grams) per spike, relative, (*X*)		100.00	±2.8743
Culm length, subject	Y 640 (1907)	32.25	±1.6737
	Y 640a (1908)	17.43	±0.3768
	Y 1122 (1907)	26.54	±2.5234
	Y 1122 (1908)	8.96	±1.2649
	Y 1123 (1907)	27.65	±3.0898
	Y 1123 (1908)	11.26	±0.0691
Spike length, relative	X 640 (1907)	27.14	±1.3727
	X 640a (1908)	21.46	±0.4586
	X 1122 (1907)	20.35	±2.3322
	X 1122 (1908)	13.52	±1.3688
	X 1123 (1907)	21.40	±2.3255
	X 1123 (1908)	11 32	±0.0695
Culm length, subject	Y 640 (1907)	24.26	±1.4590
	Y 640a (1908)	17.43	±0.3766
	Y 640b (1908)	17.85	±0.5752
	Y 1122 (1907)	26.61	±1.0587
	Y 1122 (1908)	9.30	±0.6591
	Y 1123 (1907)	26.90	±2.9859
	Y 1123 (1908)	15.68	±0.3918
Number of grains per spike, relative	X 640 (1907)	76.83	±4.8846
	X 640a (1908)	46.60	±1.1716
	X 640b (1908)	53.29	±2.1503
	X 1122 (1907)	72.53	±3.8681
	X 1122 (1908)	22.52	±1.6618
	X 1123 (1907)	54.50	±7.5257
	X 1123 (1908)	34.82	±0.9469

Taking the coefficient of variability for each character and for each strain for both years, we have:

TABLE 11.—*Coefficient of variability, 1907 and 1908.*

Character.	1907. 640.	1907. 1122.	1907. 1123.	1907. Average.	1908. 640.	1908. 1122.	1908. 1123.	1908. 25 races.	1908. Average.
Culm length......cm.	28.25*	26.57*	27.27*	27.36	17.42*	9.13*	13.47*	18.37	22.99
Spike length......cm.	27.14	20.35	21.40	22.96	21.46	13.52	11.32	....	19.19
Number of grains per spike..............	76.83	72.53	54.50	67.95	49.94*	22.52	34.82	45.84	50.99
Number of culms per plant..............								73.24 72.13 73.85	73.07
Weight of grain per spike.........grams								100.00	100.00

* Mean of two determinations.

From this table it is evident that, although, as previously discussed, there was a uniform falling off in the degree of variability of each character as expressed by the coefficient when the year 1908 is compared with 1907, there is also shown in this table, what has not hitherto been brought out—the fact that among the different strains taken one with another, with but two exceptions the *comparative variability of each character remained the same for both years* where two years' data are present.

In both 1907 and 1908 the average variability in length of culm and spike were not widely different, the former being rather the more variable of the two. In each year the variability in the number of grains per spike was greater than the variability in culm or spike length; and in each year by about the same amount—viz., by about 2½ times as much. The variability in number of culms per plant (1908) was in turn about 1½ times that of the variability in the number of grains per spike for 1908. The maximum of variability was found in the weight of grain per spike, at 100 in 1908.

TABLE 12.—*Coefficient of variability of culm length, 1907.*

No. 640	32.25		
640	24.26		
Average		28.25	
1122	26.54		
1122	26.61		
Average		26.57	
1123	27.65		
1123	26.90		
Average		27.27	
General average, 1907			27.36

TABLE 13.—*Coefficient of variability of culm length, 1908.*

No. 640	17.43	
640	17.43	
640	17.85	
Average		17.57
1122	8.96	
1122	9.30	
Average		9.13

TABLE 13—Continued.

No. 1123	11.26		
1123	15.68		
Average		13.47	
General average, 1908			13.39
Total decrease from 1907 to 1908			31.97
Percentage decrease from 1907 to 1908			51.06

TABLE 14.—*Coefficient of variability of spike length, 1907 and 1908.*

1907:		
No. 640	27.14	
1122	20.35	
1123	21.40	
Average, 1907		22.96
1908:		
No. 640	21.46	
1122	13.52	
1123	11.32	
Average, 1908		15.43
Total decrease from 1907 to 1908		7.53
Percentage decrease from 1907 to 1908		32.70

TABLE 15.—*Coefficient of variability of number of grains per spike, 1907 and 1908.*

1907:		
No. 640	76.83	
1122	72.53	
1123	54.50	
Average		67.95
1908:		
No. 640	{46.60 53.29	
1122	22.52	
1123	34.82	
Average, 1908		39.31
Total decrease from 1907 to 1908		28.64
Percentage decrease from 1907 to 1908		42.1

INDIVIDUAL VARIATION

The relations brought out by the coefficient of variability are further illustrated in a graphical way in figures 10 and 11, which show individual variation in No. 640-5 and in No. 1123-2 and No. 1123-3 for 1908.

In each illustration, the first graph shows the individual variation in culm length among all the plants of 1908 derived from some single plant parent of Nos. 640 and 1122, respectively, in 1907, and arranged in the consecutive order of increasing culm lengths. The succeeding graphs on each plate show the corresponding spike lengths, number of spikelets, number of flowers per spike, and number of grains per spike, respectively, for each of the plants plotted above on the graph for culm lengths. The relative variability of these latter characters as compared with one another is thus graphically brought out. The slight variability in spike length and in the number of spikelets to the head, as compared with the variability in the number of flowers per spike and in the number of grains per spike, is clearly shown in this manner. It will be seen that the relative variability of the characters chosen, in comparison with culm length, is the same in the two plants derived from No. 1123 as in No. 640. The probabilities are that the relative variability of these characters in the *vulgare* wheat varieties as a whole is substantially the same as is shown to be the case in the strains chosen.

GENERAL CONCLUSIONS

1. The data obtained from three pure strains of wheat, for which biometric records have been kept for two years, indicate the importance of place-variation in the general variation phenomena of the strains in question.

2. In respect of culm length, spike length, and number of grains per spike there was both absolute decrease in variability (denoted by the standard deviation), and comparative decrease (denoted by the coefficient of variability) for all three races from 1907 to 1908. Reduced to percentages, the average decrease in the coefficient of variability from 1907 to 1908 was 51 per cent for culm length, 32.7 per cent for spike length, and 42.1 per cent for number of grains per spike; the net average decrease for all three characters being 41.9 per cent.

3 The modes and means of culm length and number of grains per spike for each strain underwent a positive (upward) shifting from 1907 to 1908, amounting to an average of 54 per cent in the case of

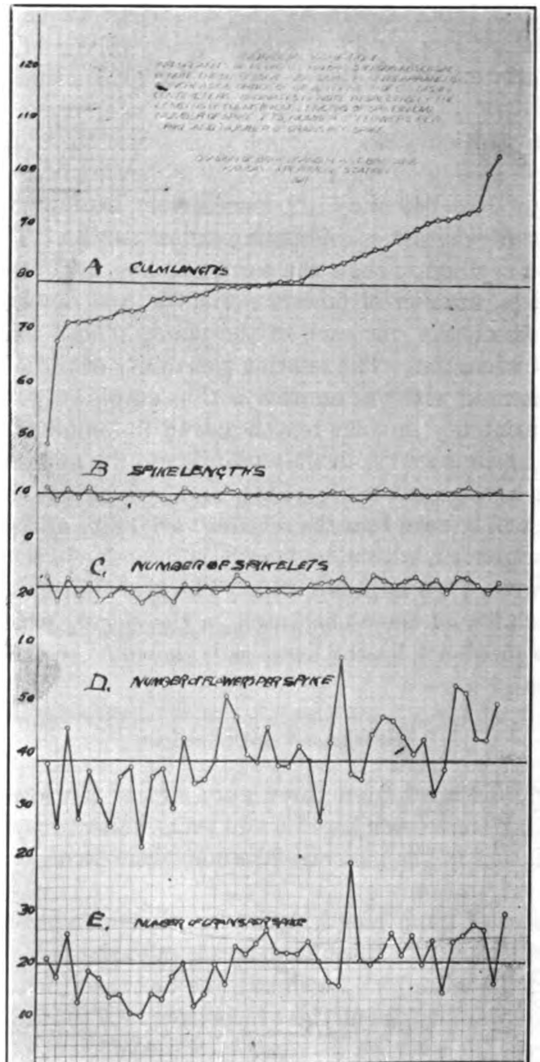

FIG. 10. INDIVIDUAL VARIATION.

In 43 plants of pedigree No. 640-5 in 1908. Abscissae denote the successive individual plants ranged in increasing order of mean length of culms in centimeters. Ordinates denote respectively the lengths of spike (in centimeters) number of flowers per spike and number of culms per spike.

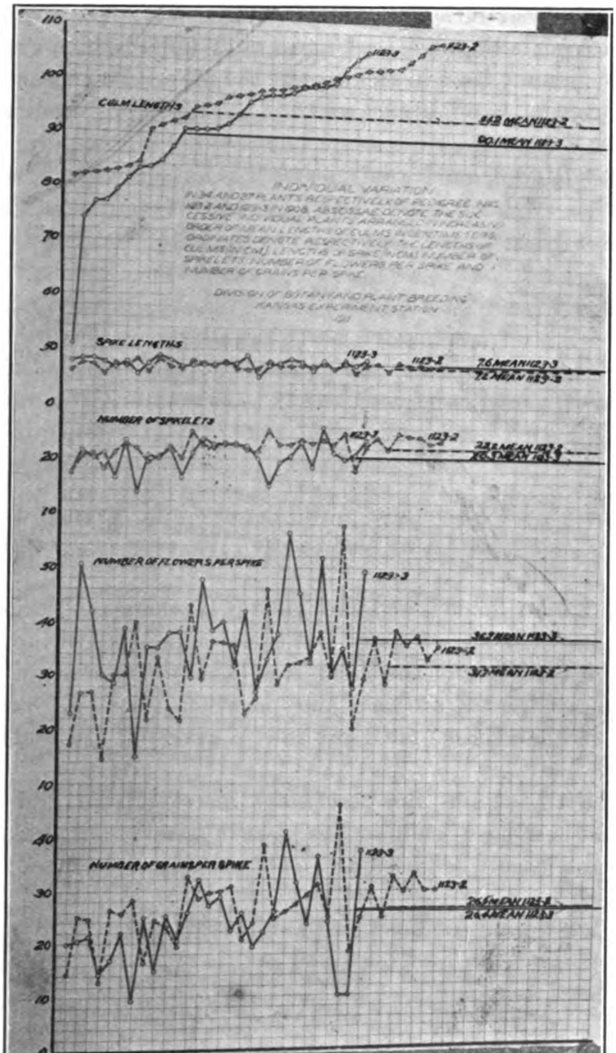

Fig. 11. Individual Variation.

In 34 and 27 plants respectively, of pedigree Nos. 1123-2 and 1123-3 in 1908. Abscissae denote the successive individual plants ranged in increasing order of mean length of culms in centimeters. Ordinates denote respectively the lengths of culms (in centimeters) lengths of spike (in centimeters,) number of spikelets, number of flowers per spike and number of grains per spike.

culm length and of 40 per cent in the case of number of grains per spike. In the case of length of spike there was a positive upward shifting also of both mode and mean, and for all three races, but by a lesser amount than in the case of the other two characters; the range being from 15 to 40 per cent for the mode and from 17 to 26 per cent for the mean.

4. This shifting of modes and means was not alike in amount in all three strains. Arranged in order of amount of increase in the mean estimated in percentages, they stand in the following rank:

TABLE 16.

No.	Culm length.	Spike length.	Number of grains per spike.
640	3	2	3
1122	2	3	2
1123	1	1	1

For all three characters and all three races (one instance excepted) the shifting was greatest in amount in 1123, next greatest in 1122, and least in 640.

5. Explanation for this relative amount of change is furnished by the field plots of 1908. The order of the strains in respect to amount of percentage shifting of the mean was exactly the order of relative seasonal superiority of the field plots in which they were located, as measured by the average yield per row in grams of the control rows of wheat.

6. For all the strains the percentage increase from 1907 to 1908 was greatest in mean of culm length, next in mean of number of grains per spike, and least in spike length. The shifting of the mode followed the same order.

7. The correlation coefficients stood as follows for 1908:

TABLE 17.

Subject.	Relative.	r.
1. Number of culms per plant	Weight of grain per spike	0.8345
2. Culm length	Number of grains per spike	0.6684
3. Culm length	Spike length	0.2922
4. Number of culms per plant	Culm length	0.2810
5. Number of culms per plant	Number of grains per spike	0.1805

For 1907, Nos. 1, 4, and 5 in the preceding table were not computed. The relative order of Nos. 2 and 3 was the same as in 1908.

There was a very slight increase in the correlation coefficient from 1907 to 1908 as between culm length and number of grains per spike, and a very considerable decrease as between culm length and spike length.

8. The weight of grain per head increases sharply and continuously with the increase in tillering. The number of grains per head increases until the plants have 15 to 16 culms per plant and then decreases with further tillering. The height of the stalks increases until the plants have 19 to 21 culms per plant, and then decreases.

9. The general conclusions are as follows:

A better growing season reduces variability in pure strains of wheat so far as the characters investigated are concerned.

Tillering is, in all probability, the most important vegetative phenomenon in the growth of the wheat plant, so far as the yield is concerned, since it is extremely highly correlated with the weight of grain per head.

Selection as often practiced, of heads of wheat on the basis of the weight of grain or of the number of grains produced per head is scientifically useless, since these are among the most variable characters within the same strain from season to season.

Seasonal factors and soil factors are probably sufficient to overwhelm hereditary distinctions in yield among strains of wheat in good seasons.

Improvement of wheat through breeding by selection is impossible without quantitative estimation of the part played by seasonal and soil factors in inducing variability.

A STUDY OF THE LARGE AND SMALL GRAIN QUESTION[a]

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Much work is being conducted leading toward the improvement of the small grains. To workers in this line the question of size of seed is an important one and needs much consideration in breeding work. The common advice given to a grower is that he should reclean his seed in order to obtain only the largest and plumpest for sowing. Many experiments have been conducted to determine the relative value of

[a] Paper 17, Department of Plant Breeding, Cornell University, Ithaca, N. Y.

light and heavy seed. Among these, and possibly the best known of all such experiments, are those under the direction of Prof. C. A. Zavitz, at Guelph. In these experiments Prof. Zavitz worked with hand-picked seed, thus being sure to have a good separation of light and heavy grains. The results show a good gain in yield per acre from the heavy seed.

The writer has sown hand-picked seed for a number of varieties of oats and found that in every case the larger yield was obtained from the heavy seed. In another test with oats in which large and small kernels from the same head were compared the large seed gave a greater yield.

Although there have been many experiments comparing large and small seed, few studies have been made to determine the parentage of these large seeds. Do large seeds come from large plants, or do the smaller, low-yielding plants produce a large percentage of the heavy seed? Another point along this line which needs consideration is the relative value of small seed from large plants, as compared with large, from small plants.

Waldron has made a valuable contribution to the study of light and heavy seed. His data were taken on oats, but he also made some calculations on data taken by Dr. T. L. Lyon and reported in Bulletin 78 of the Bureau of Plant Industry. Waldron's paper shows the value of the statistical method of analysis in dealing with such problems. He suggests the importance of a closer analysis of our plants to determine some of the fundamental truths which may serve as a basis for improvement. The results, especially with respect to oats, reported in this paper cast some doubt on the wisdom of planting only the heaviest seed. The data as reported show that the heaviest seed come from the smaller rather than from the larger plants. This immediately raises the question as to whether one can reasonably expect gains from the largest seed.

Waldron arranged his data in correlation tables and determined the correlation between the following characters: Average weight of seed and number of grains; average weight of seed and length of head; and average weight of seed and length of culm. The calculations showed a negative correlation of -0.595 ± 0.013 between average weight of seed and number of grains, while for the average weight of seed and length of head and average weight of seed and length of culm correlation coefficients of -0.511 ± 0.015 and -0.404 ± 0.017 were found. The constants show that the larger kernels are borne by short plants having short heads and producing only

a small number of kernels per head, or, in other words, the smallest plants are the ones which produce the heaviest seed. From these data then it seems possible that in sowing the heaviest seed one is not using seed from the best-yielding plants.

While conducting some experiments with pure lines of wheat the author has collected data which are interesting in this connection. Notes similar to those taken by Waldron were obtained on a number of characters of wheat and have been brought together to determine what kind of plants produce the large seed. As stated above, these

TABLE 1.—*Correlation between height of plant and yield.*

[Height subject, yield relative. $r = 0.294 \pm 0.032d$.]

Height in centimeters.	Yield. 0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	Totals.
45–50	1																		1
50–55																			0
55–60																			0
60–65	1																		1
65–70	2	1																	3
70–75	3	1	1	1	1														7
75–80	4	3	2			1													10
80–85	1	5	2																8
85–90	7	6	5	2	3	1	2												26
90–95	4	10	3	7	2	4	2			1		1							34
95–100	5	7	13	6	3	4	5	2	2		1	1					1		50
100–105	3	13	16	10	12	7	4		2		2						1		70
105–110	3	9	13	5	12	3	2	3	2	3	2		3			1		1	62
110–115	3	2	21	4	7	7	9		1	1	2	1			1	1			60
115–120		1	9	4	4	2	2		1	1				1					25
120–125		1	3	1	1						1							1	8
125–130				1															1
Totals.	37	59	88	41	45	29	26	5	8	6	8	3	3	1	1	2	2	2	366

data were collected on a pure line of wheat which has been under observation three seasons.

Such data as length of culm, length of head, number of spikelets, number of kernels, weight of grain, and average weight of kernel per plant were taken. The data were taken on each culm separately and then averaged, and the averages are used to represent the plant. In all of the tables the plant has been used as the individual and not the culm. Other studies have shown that in general we may expect similar correlation when the culms are used as the individuals rather than the plants themselves.

The correlation existing between height of plant and yield is shown by Table 1. The height of plant was measured in centimeters and the yield taken in grams. There exists a positive correlation of 0.294 ± 0.032. This is not as high as would be expected from the characters used, yet since all the culms per plant were measured and the average of these taken to represent the height of plant it is possible that the correlation may be affected to no small degree. It often happens that a high-yielding plant will have a few very short culms,

TABLE 2.—*Correlation between number of grains and yield.*

[Number of grains subject, yield relative. $r = 0.985 \pm 0.001$.]

Number of grains.	Yield. 0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	Totals.
1–25	29																		29
26–50	8	36																	44
51–75		23	56																79
76–100			31	21															52
101–125			1	19	23														43
126–150				1	19	10													30
151–175					2	15	10												27
176–200					1	4	15	2											22
201–225							1	3	3										7
226–250									5	3									8
251–275										1									1
276–300										2	6		1						9
301–325											2	2	1						5
326–350												1		1					2
351–375													1		1				2
376–400																1			1
401–425																1			1
426–450																		1	1
451–475																	2		2
476–500																			0
501–525																		1	1
Totals.	37	59	88	41	45	29	26	5	8	6	8	3	3	1	1	2	2	2	366

and when these are averaged with the others the height of plant is cut down and the correlation may thus be affected. This correlation shows, however, that as the plants increase in height the yield is increased, and therefore the tallest plants will in general be the heaviest yielders.

The correlation existing between number of kernels per plant and yield is shown by Table 2.

TABLE 3.—*Correlation between height and average weight of grains.*

[Height subject, average weight of seed relative. $r = 0.278 \pm 0.033$.]

Height in centimeters.	Average weight of grains.																												Totals.
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	
45–50																				1									1
50–55																													0
55–60																													0
60–65																					1								1
65–70													1				1	1											3
70–75				1											1			1	1				1	2					7
75–80					1						1						3		3				2						10
80–85										1		1	1		1	1	1	1	1										8
85–90							1							3	2		3	5	5	4		2						1	26
90–95			1		1				1				2			2	3	3	4	5	6	1	1	2	1	1			34
95–100									1			2	2		1	4	3	3	6	8	11	4	4	1					50
100–105									1			1	1	2	2	5	5	6	3	11	9	9	11	3		1			70
105–110	1												3	1		4	8	8	10	3	7	6	5	2	2	1		1	62
110–115											1	1	1	1	1	2	2	1	3	10	17	5	7	3	3	1	1		60
115–120														1	1		2	2	1	4	2	1	3	3	2	2	1		25
120–125																		1	1			2	1	1			2		8
125–130																				1									1
Totals.	1	0	1	1	2	0	1	0	3	1	2	5	11	8	9	18	31	32	38	47	53	30	35	17	8	6	4	2	366

TABLE 4.—*Correlation between number of grains and average weight of grains.*

[Number of grains subject, average weight of grains relative. $r = 0.251 \pm 0.033$.]

Number of grains.	Average weight of grains.																												Totals.
	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26	26-27	27-28	28-29	29-30	30-31	31-32	32-33	33-34	34-35	35-36	36-37	37-38	38-39	39-40	40-41	41-42	42-43	43-44	
0-25	1			1	1		1				1	2	1	1		2	1	3	2	5	3		3	1					29
25-50			1						1	1	1	1	3	1	4	1	5	5	6	3	2	4	2	2	1				44
50-75									1			1	3	2	2	4	8	9	12	6	10	6	4	5	1	3		2	79
75-100									1			1	4	2	2	2	5	5	3	6	7	3	4	2	2		3		52
100-125					1											3	3	2	5	6	7	4	7	4			1		43
125-150														2		2	3	4	2	4	5	3	3	1		1			30
150-175																3	2		2	5	8	3	2		2				27
175-200															1	1	3	1	2	7	4		3						22
200-225																		1		1	1		2	1		1			7
225-250																		1		1	1	3	1		1				8
250-275																						1							1
275-300																		1		1	3	3				1			9
300-325																			2	1	1			1					5
325-350																					1				1				2
350-375																			1				1						2
375-400																							1						1
400-425																							1						1
425-450																							1						1
450-475																			1	1									2
475-500																													0
500-525																	1												1
Totals.	1	0	1	1	2	0	1	0	3	1	2	5	11	8	9	18	31	32	38	47	53	30	35	17	8	6	4	2	366

TABLE 5.—*Correlation between yield and average weight of grains.*

[Yield subject, average weight of grains relative. $r = 0.327 \pm 0.031$.]

Yield in grams.	Average weight of grains in milligrams.																												Totals.
	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26	26-27	27-28	28-29	29-30	30-31	31-32	32-33	33-34	34-35	35-36	36-37	37-38	38-39	39-40	40-41	41-42	42-43	43-44	
0–1	1		1	1	1		1				2	3	3	1		2	1	4	4	5	3		3	1					37
1–2									2	1		1	4	3	6	2	10	5	7	4	5	4	2	2	1				59
2–3					1				1			1	4	2	2	5	8	12	9	10	9	8	5	5	1	3		2	88
3–4														1		3	3	3	6	3	9	2	4	2	2		3		41
4–5														1		4	3	4	4	8	7	3	6	4			1		45
5–6																2	4	1	2	5	6	3	4	1		1			29
6–7															1		1	1	2	7	6	3	3		2				26
7–8																				1	2		2						5
8–9																		1		1	1	1	2	1		1			8
9–10																		1		1		3			1				6
10–11																			2		3	3							8
11–12																				1	2								3
12–13																			1					1		1			3
13–14																									1				1
14–15																							1						1
15–16																							2						2
16–17																			1	1									2
17–18																	1						1						2
Totals	1	0	1	1	2	0	1	0	3	1	2	5	11	8	9	18	31	32	38	47	53	30	35	17	8	6	4	2	366

As would be expected, this gives a very high correlation coefficient, which is 0.985 ± 0.001. This is abnormally high, yet we may expect rather high correlation between these characters in most cases.

These two tables are given in order to call to mind to what degree the two characters, height and number of kernels are associated with yield in the material under observation.

The correlation of height with average weight of grains is shown by Table 3. Here we find a positive correlation of 0.278 ± 0.033, which indicates that for these data there is as high a degree of correlation as exists for height and yield. This is quite the opposite of −0.404 ± 0.017, which was found by Waldron with oats. The wheat data which were reported by Lyon and arranged by Waldron gave a correlation of 0.16 ± 0.034 for the same characters.

It is seen then that by selecting the tall plants one is also isolating those which produce a larger seed.

The correlation between total number of grains per plant and average weight of grains is shown by Table 4.

A correlation coefficient of 0.251 ± 0.033 is obtained, which shows that the plants producing the largest number of grains also produce heaviest seed, as a general rule.

The correlation existing between yield in grams and average weight of grains in milligrams is shown by Table 5.

Here we find a correlation coefficient of 0.327 ± 0.031, which denotes that high-yielding plants produce heavy seed.

The foregoing studies show that yield is associated with tall plants and plants which produce a large number of kernels. These results would from the nature of the character be expected. At the same time the heaviest seed are produced in general on the tallest plants, plants producing the largest number of seed and the heaviest yielding plants.

TABLE 6.—*Correlation coefficients for the different characters studied.*

Characters.	Correlation coefficients.
Height of plant and yield	0.294 ± 0.032
Number of kernels per plant and yield	0.985 ± 0.001
Height of plant and average weight of grains	0.278 ± 0.033
Total number of grains per plant and average weight of grains	0.251 ± 0.033
Yield in grams and average weight of grains in milligrams	0.327 ± 0.031

As stated above, these data were taken on a pure line of wheat, yet we would expect similar results from a mixed race, and in fact

such is the case, as is shown by other data which have been obtained at the plant breeding laboratory at Cornell University. It is also important to note that the pure line here studied is a different variety from that of the mixed race mentioned above, which indicates, in a small way, that we may expect that these results will hold for varieties in general. It is necessary, however, to study several varieties before definite conclusions can be drawn in this connection.

The plants were grown in drills similar to field conditions, with the exception that they were not planted quite so thick. It does not seem probable, however, that the correlations would be much affected by this fact.

There is no doubt that there would be considerable variation within the same variety from year to year. In fact, our studies at the Cornell laboratory on correlation of small grains show that this is true. This seasonal variation is due to many factors which influence a plant while it is developing. Such factors as season, high or low average temperature, or changes in soil conditions play a very important part in increasing or decreasing the variation or correlation. On the other hand, it is probable that we may expect that similar results will be obtained for any year when the general growth conditions are the same.

These correlation coefficient are entirely opposite to those reported by Waldron[b] in his work with oats. The correlations reported in his paper, as stated above, all show that heavy seed did not come from the tallest plants, or plants producing the most seed. The fact that his studies were on oats may have made some little difference. However, data taken on oats that same season as on the wheat show that we do not get the negative correlation, as Waldron did, but rather positive correlation. It is well to state further that a variety of oats grown at this station the same season that Waldron grew his oats at North Dakota shows positive correlation for these same characters. The oats studied at this station were pure lines.

An important question in this connection is, What influences were at work to produce such high negative correlation in the case of Waldron's oats and not in the wheat or oats studied at this station? No doubt there were factors at work which are as yet not understood. It may be due in part to the fact that his oats were produced under conditions entirely different from those under which the crops at this station matured. These widely varying results emphasize the impor-

[b] Waldron L. R. A Suggestion Regarding Heavy and Light Seed Grain. *American Naturalist*, Vol. xliv, p. 48–56, Jan. 1910.

tance of much study along this line under vastly differing growth conditions.

However, from the data at hand and other data which have been obtained at this station we are safe in stating that if large (heavy) seeds of wheat (also oats) are used for planting they will come from the tallest, heaviest yielding individuals. Then if there is a tendency for the parent plant to reproduce its type a larger yield may be expected from the heavier seed.

COMPETITION IN CEREALS

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Competition as a factor in modifying the character of plant populations, by means of destroying or hindering the weak or least fit to survive under the particular environment, has been recognized as one of importance since Darwin pointed out its effective workings.

While thus recognized as a natural means of maintaining the vigor and strength of native vegetation, it has not been recognized as a means of maintaining the yield and vigor of our cultivated crops. Our common cereals have been cultivated for many thousand years with practically no attention to selection or grading until quite recent times. If any change has taken place, there has been a slow improvement, so far as we are able to judge by the limited information at hand. It is possible that the custom of placing in the soil seeds for two or three times as many plants as are really necessary to occupy the land has resulted in a continuous natural selection of the strongest and most productive.

In the fall of 1907 a series of small winter wheat plats were put out at the Nebraska Experiment Station for the purpose of securing some data on the amount of natural elimination of plants taking place under various rates of planting, and also to determine to what degree plants coming from undeveloped or small seeds might be eliminated when planted in competition with plants from large well developed seeds.

The plan adopted was to plant seeds of wheat at various distances, namely, ¼ inch, ½ inch, 1 inch, and 1½ inches apart. This was done with two varieties—Turkey Red and Big Frame. Then to test the effect of competition on plants growing from large, well developed and poorly-developed seeds, respectively, seeds of the two varieties

were alternated. For example, large seed of Turkey Red would be alternated with undeveloped seed of Big Frame at the various rates from ¼ inch to 1½ inches. A reciprocal series was also planted, using poorly developed Turkey Red, in competition with well developed Big Frame. The series were duplicated and alternated with check plats, there being 96 plats all told. The experiment was repeated with winter wheat in 1909 and 1910, and with two varieties of oats in 1910, using large and small seeds, but all well-developed. The wheat plats were completely winterkilled in 1910.

Decrease in Plants from Planting to Harvest.—The number of seeds planted per plat at each rate were 672 when ¼ inch apart, 336, 168 and 112, respectively, at the other rates. The number of plats in a series, including checks, was 48, and repeated, making 96 in all. The plats each consisted of 4 rows 36 inches long and 8 inches apart, or the area of the plat was approximately 32 by 36 inches.

On October 22 the living plants in each case were counted, and again at harvest time all were counted. For ease of comparison all data were reduced to the basis of 100 grains planted in the following table:

TABLE 1.—*Combined data for Turkey Red and Big Frame wheat, showing survival of plants at various rates of planting, 1908.*

Distance of planting in inches.	Seeds planted.	Number of plants October 22, 1907.	Number of plants harvested 1908.	Decrease from October to harvest.
1½	100	89	77	12
1	100	87	70	17
½	100	83	66	17
¼	100	83	60	23
Average	100	85.5	68.2	17.2

For every 100 seeds planted there was an average of 85.5 live plants October 22, and 68.2 plants came to maturity. Between October 22 and harvest time there was an average decrease of 17.2 plats from various causes. That some of this decrease was due to competition is shown by the fact that about twice as many were lost under thick planting as thin.

In 1909 the experiment was continued but under unfavorable conditions. The fall and winter proved to be very dry, so the fall growth was rather small, and winterkilling was heavy. The data show that for every 100 seeds planted there were 74 live plants December 2, 41 at harvest time, and an average decrease of 33 plants from fall

to harvest. Again the greatest relative decrease is in the thicker plantings.

TABLE 2.—*Combined data for Turkey Red and Big Frame wheat, showing survival of plants at various rates of planting, 1909.*

Distance of planting in inches.	Number of seeds planted.	Number of plants December 2, 1908.	Number of plants harvested.	Decrease from December 1908, to harvest.
1½	100	76	51	25
1	100	78	44	34
½	100	74	37	37
¼	100	69	31	38
Average	100	74	41	33

In 1910 the winter wheat plats were winterkilled and no data were secured. A series of oat plats, planted in the same manner, gave data similar to that secured with winter wheat, as shown in Table 3.

TABLE 3.—*Combined data for two varieties of oats showing survival of plants at various rates of planting, 1910.*

Distance of planting in inches.	Number of seeds planted.	Germination.	Number of plants harvested.	Decrease from planting to harvest.
2	100	....	91	9
1	100	....	75	25
½	100	....	64	36
¼	100	....	64	36
Average	100	....	73.5	26.5

The per cent of germination was not recorded. There was an average of 73.5 per cent as many plants harvested as seeds planted, and only 64 per cent with the thickest plantings.

It appears from data cited that there is a decrease of about 15 to 30 per cent in the number of plants from spring to harvest. There are many causes of this decrease, such as insects, diseases and accidents of various kinds, but after these are accounted for it is evident that we still have a loss of plants through competition in the thicker plantings. It seems natural that the plants eliminated should be those that from any cause are weak or slow in development. Plants from undeveloped seeds are usually smaller in early growth, although later the plants may become vigorous enough. As mentioned early in the paper, in certain plats well-developed seeds were alternated with undeveloped seeds at the various rates, for the purpose of determining

whether the more vigorous plants from the large seeds would tend to eliminate the less vigorous plants from the poor seed. Table 4 is a summary of data of 48 plats of winter wheat, all rates of planting.

TABLE 4.—*Combined data for Turkey Red and Big Frame winter wheat, to show effect of competition of two grades of seed, 1908.*

Description of seed.	Manner of planting.	Number of seeds planted.	Number of plants October, 22.	Number of plants harvested.	Decrease from October to harvest.
Well-developed, plump.........	Alone	100	87	72	15
Undeveloped....................	Alone	100	80	65	15
Well-developed, plump.........	In competition	100	89	79	10
Undeveloped....................	In competition	100	85	60	25

Both grades of seed showed the same decrease from October to harvest, when planted alone, i.e., each grade in a plat to itself. However, in competition, when the two grades were alternated, plants from the well-developed seed showed a marked advantage.[a] Evidently the initial advantage gained by the more vigorous plants from large plump seed enabled them to crowd out the less vigorous plants when planted in competition. Observations made in the field show that early in the season when rapid growth first begins, whether with fall-sown or spring-sown crops, if for any cause a plant is slow in starting, and it is located between quick-starting plants, the latter will soon shade it and have advantage in various ways, that the slower plant is permanently retarded, whereas a similar slow starting plant, among others of its kind, may fully recover in time and at harvest be as vigorous as any.

TABLE 5.—*Combined data for Turkey Red and Big Frame winter wheat, to show effect of competition of two grades of seed, 1909.*

Description of seed.	Manner of planting.	Number of seeds planted.	Number of plants December 2, 1908.	Number of plants harvested, 1909.	Decrease from December to harvest.
Well-developed, plump.........	Alone	100	74	43	31
Undeveloped....................	Alone	100	67	34	33
Well-developed, plump.........	In competition	100	81	50	31
Undeveloped....................	In competition	100	75	36	39
Average........................	....	....	74.2	41	33.2

The data for 1909 are irregular, owing to the unfavorable conditions under which grown and severe winterkilling. All grades were so

[a] The advantage was not as pronounced in other tests. See table 8.

severely winterkilled that little competition could take place in the spring growth, but again the highest per cent surviving plants was with the best seed in competition and the greatest elimination among plants from poorly developed seeds in competition.

In 1910, Swedish Select (white) and Garton No. 70 (black) were sown in competition, alternating large and small seeds at various rates from ¼ to 2 inches, and sowing large seed and small seed alone at the various rates—48 plats in all.

TABLE 6.—*Large and small seeds of two varieties of oats, sown at various rates and in competition, 1910.*

Description of seed.	Manner of planting.	Number of seeds sown.	Number of plants harvested.	Decrease.
Small seed	Alone	100	60	40
Large seed	Alone	100	65	35
Small seed	In competition	100	68	32
Large seed	In competition	100	74	26

In this case the large seed in competition did not show a greater advantage than when the large and small were sown alone. For some reason, in every case with both wheat and oats, two varieties in competition have given a greater number of plants at harvest or greater yield than when either variety was sown alone.

Table 7 is a summary of data of the number of plants surviving at the various rates of seeding for three years.

TABLE 7.—*Number of plants harvested for 3 years, on basis of 100 grains planted, at various rates.*

Distance of planting in inches.	Number of seeds planted.	Winter wheat 1908.	Winter wheat, 1909.	Oats 1910.	Average.
1½	100	77	51	91	73
1	100	70	44	75	63
½	100	66	37	64	56
¼	100	60	31	64	52
Average	100	68.2	41	73.5	61

The results indicate that about two-thirds as many plants are harvested as seeds planted, as an average of all rates of planting. The number surviving, where the planting is thin, is about 40 per cent greater than where the planting is thick. This greater decrease in the thick planting is apparently due to the effect of competition among the plants.

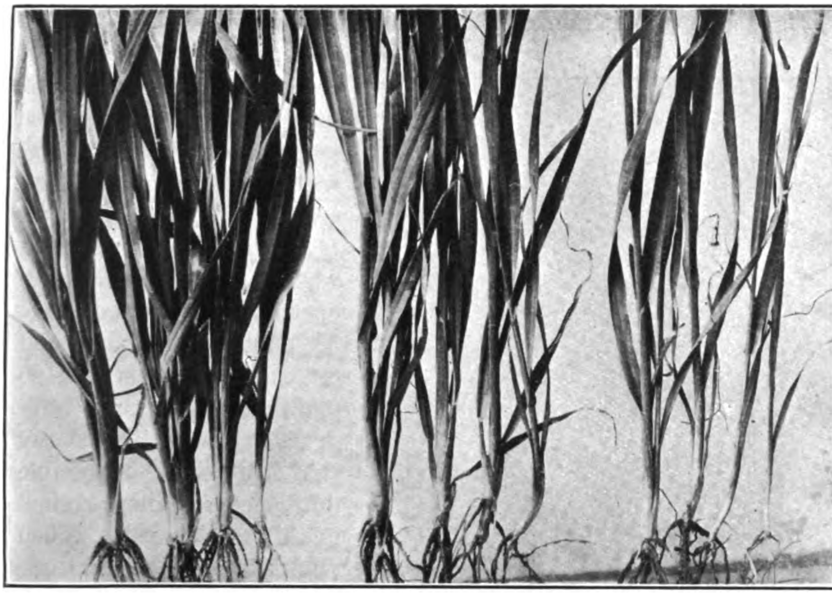

FIG. 1. THREE SETS OF KHERSON OAT PLANTS.

Grown at three rates of seeding, namely, 4 pecks per acre, 8 pecks, and 16 pecks. At this time (plants 8 inches in height) the plants from the thin seeding were producing tillers freely, while very little tendency to tiller was shown by the plants from thick planting.

FIG. 2. SIXTEEN TYPICAL KHERSON OAT PLANTS.

From plant sown at rate of 16 pecks per acre. Plants about 8 inches high. At the right are about 4 plants that probably will not survive until harvest, or, if they do, will not produce more than a few seeds. In Fig. 3 are shown the relative size of the smaller plants at harvest time.

FIG. 3. RELATIVE SIZE OF LARGE AND SMALL PLANTS AT HARVEST. [KHERSON OATS.]

From plat sown at rate of 16 pecks per acre. When the plants are about 8 inches high the stronger begin to grow rapidly, while the weaker plants either die or make slender growth producing only a few seeds.

Table 8 is a summary of data where large, well-developed seed was compared with small or undeveloped seed.

As an average for 3 years when the small or undeveloped seed are planted alone, 53 plants were harvested for each 100 seeds and 60 plants from the large well-developed seed. This shows that there was considerable difference in the original quality of the seed. When planted in competition there is a higher percentage of survivors in both cases—a fact noted every year. The survivors from large seed in competition, however, were 68, or 13 more than from the small seed, while planted alone the advantage was only 60 to 53—an advantage of 7 plants. Since the total reduction in number of plants was 41 per cent on an average, the advantage of large seed over small is not large. It seems that there are almost as many weaklings susceptible to the effects of competition among the plants from large seed as small.

Effect of Rate of Planting on Size of Plant.—Table 9 affords an excellent example of the relation of rate of planting to yield and size of plant.

TABLE 8.—*Number of plants harvested for 3 years on basis of 100 grains planted at various rates.*

Description of seed.	Manner of planting.	Number of seeds planted.	Number of plants harvested. Winter wheat, 1908.	Winter wheat, 1909.	Oats 1910.	Average.
Small or undeveloped........	Alone	100	65	34	60	53
Large, plump.................	Alone	100	72	43	65	60
Small or undeveloped........	In competition	100	60	36	68	55
Large, plump.................	In competition	100	79	50	74	68
Average..................	....	....	69	41	67	59

TABLE 9.—*Oats, 1910. Effect of rate of planting on size of plat.*

	Spacing of plants. 2 inches.	1 inch.	½ inch.	¼ inch.
Number of seeds planted.........	100	100	100	100
Number of plants harvested......	91	75	64	64
Average yield per plat (72–144 288–576 seeds per plat)...........	94	96	87	98
Yield per plant..................	1.72	1.09	0.62	0.35

The yield per plat was not materially influenced by the rates of seeding, as the yield per plant seemed to make full adjustment to conditions, thus producing maximum yield under the thin planting.

Competition of Varieties.—As a result of the experiment, some data were secured showing the effect of competition one variety may have on another. In the case of the winter wheat, the following table shows that in 1908, when Big Frame was sown alone under the conditions of this experiment, it yielded most, but when sown in competition with Turkey Red the latter was most productive.

In the case of oats in 1910, whenever the black oats (Garton No. 70) was sown alone, it outyielded the white (Swedish Select), but when sown in competition the white returned the greatest yield.

TABLE 10.—*Competition of varieties.*

Variety.	Manner of planting.	Number of seeds planted.	Number of plants harvested.	Total yield.
				Grams.
Turkey Red....................	Alone	2576	1429	885
Big Frame.....................	Alone	2576	1784	985
Turkey Red....................	In competition	2576	1836	1190
Big Frame	In competition	2576	1712	826

TABLE 11.—*Comparative yields of two varieties of oats when sown alone and in competition. Yield per plat in grams.*

	Spacing of plants.				Average.
	2 inches.	1 inch.	½ inch.	¼ inch.	
Garton No. 70 (black)	136	143	121	146	137
Swedish Select (white)	116	116	96	119	112
Garton No. 70 (black)	102	111	110	92	104
Swedish Select (white)	142	142	155	164	151

There is a possible explanation in the early habits of growth of the two oat varieties. The black oats tend to spread out close to the ground, and make little growth in height for several weeks, while the white oats grows rapidly in height at first. When mature, both varieties are about the same height. It appears that the tall growing habit of the white oats in the early stages gives it an initial advantage not fully lost later.

Corn has always been grown rather thin, so the plants are free from competition to a large extent. Natural selection through competition has not been effective. In order to secure data on the effects of competition in corn a series of plats were started in 1905, using Hogue's Yellow Dent corn and planting at 1, 3, and 5 grains per hill. Each lot has been planted continuously at the same rate since, the results for three years being given in Nebraska Bulletin 112. In 1910, after five years continuous selection, the following results were secured:

Rate at which continuously planted in past.	Rate planted in 1910.	Yield per acre.
Grains per hill.	*Grains per hill.*	*Bushels.*
1	3	59.7
3	3	61.3
5	3	65.7

This shows a gain of 6 bushels per acre, or 10 per cent, as a result of growing the seed under competitive conditions.

SUMMARY

While the experiments are not extensive enough to fully justify conclusions, yet the data are so suggestive that it seems worth publishing at this time. These data verify the following conclusions:

1. That as the rate of planting is increased, the percentage of plants surviving until harvest is gradually decreased. The total decrease in

cases sighted, amounting to 39 per cent, and the relative survival of the thinnest stand (2 inches) and thickest stand (¼ inch) averaged 73 and 52 per cent, respectively, or a decrease of 29 per cent.

2. When large plump seeds are planted in competition with small or poorly developed seeds, the decrease in the large plump seed is 32, the small or shrunken 45 per cent, while the same grades planted alone decreased 40 per cent and 47 per cent, respectively. All grades show a marked decrease due to various causes in addition to competition, but when the two grades are planted in competition the stronger plants have an advantage in number of survivors.

3. When two varieties are planted in competition, one variety is very apt to have an advantage, which, if continued, would in time practically replace the other. It appears also that the one yielding best alone will not always be the one surviving under competition.

4. Nature seems to have a way of eliminating the weaklings (under our present system of sowing cereals) whether they come from large or small seeds. Since this elimination has been going on for ages, it does not seem that an artificial method of seed separation (as a fanning mill or screens) could increase the efficiency of seed, especially since our method of thick seeding allows nature to eliminate one-half the plants each year without affecting the yield.

5. The desirability of separating pure strains is emphasized by the suggestion that when left in competition the best yielder (when placed alone) may not dominate, but, on the other hand, a poor yielder be best able to survive competition.

A SECOND REPORT ON THE COLD RESISTANCE OF ALFALFA

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Dickinson, North Dakota.

In 1908 an extensive experiment in coöperation with the United States Department of Agriculture was inaugurated at the Dickinson Sub-Experiment Station for the main purpose of testing out the hardiness of a considerable number of alfalfas. Mr. Charles J. Brand represented the Department of Agriculture. The first year's results are found in Bulletin 185 of the Bureau of Plant Industry.[a] A study of that bulletin is necessary to a complete understanding of the present discussion.

[a] Brand, Charles J., and Waldron, L. R., Cold Resistance of Alfalfa and Some Factors Influencing It. Bulletin 185, Bureau of Plant Industry, U. S. Dept. of Agriculture, Washington.

Plan of Experiment.—In the spring of 1908, 68 place-strains or varieties were seeded in both hill and drill rows. These strains came from the most important alfalfa-growing regions of the world and no doubt represented the average alfalfa seed of today in respect to hardiness. The results obtained, after the plants had passed through one winter, were very diverse, ranging from complete loss upon the one hand to almost complete immunity from loss upon the other. A brief summary of the results may be found in Table 1. The data of a few of the rows are omitted, but such rows have no present interest for us as they suffered a complete loss the first winter.

Winter Weather, 1909-10.—Aside from March, which was abnormally warm in 1910, the winter of 1909–10 was considerably colder than the average winter. There were about five periods of cold during the winter, the first one beginning in November and the latter culminating in February, at which time the absolute minimum of − 40° F. was reached. From the standpoint of thermometer readings alone, the winter may be considered to have been very severe, but another factor entered which decreased the severity greatly as far as certain vegetation was concerned.

The first snow of any importance fell November 13 and afforded some, though not ample, protection from the concurrent cold weather. This snow soon melted, but on December 4, at the beginning of the next cold period, snow again fell and lasted, along with other snow that fell, until the winter break-up in March. During most of the winter, then, surface vegetation was well protected by a snow blanket, much better than ordinarily obtains in this region.

In order to show more clearly the relation between the depth and continuity of the snow blanket, and the minimum temperatures, Chart I is presented. The snow measurements for this chart were taken almost entirely upon the alfalfa nursery and thus represent the conditions to which the alfalfa was subject. The temperatures are the means of the minima for 5-day periods through the winter. The chart shows a continuous blanket of snow from early in December until well along in March. Another significant thing is the increased depth of snow at the periods of greatest cold. This is especially noticeable during the very severe cold of February. At this time the snow on the alfalfa nursery attained a depth of 11½ inches and, at the same time, one 5-day period had a mean minimum of −30.4° F.

As evidence of the physiologically mild winter, the condition of the red clover plats during the season of 1910 may be cited. Previous to this winter, practically no clover had survived on the station farm with

a less loss than 50 per cent. During the winter of 1908–09 the clover loss was total, except few a square feet that secured a little snow protection. But during the winter of 1909–10 clover suffered little or no loss by reason of the cold weather. Three of a block of 5 plats had practically perfect stands while the 2 other plats had stands of 90 and 95 per cent.

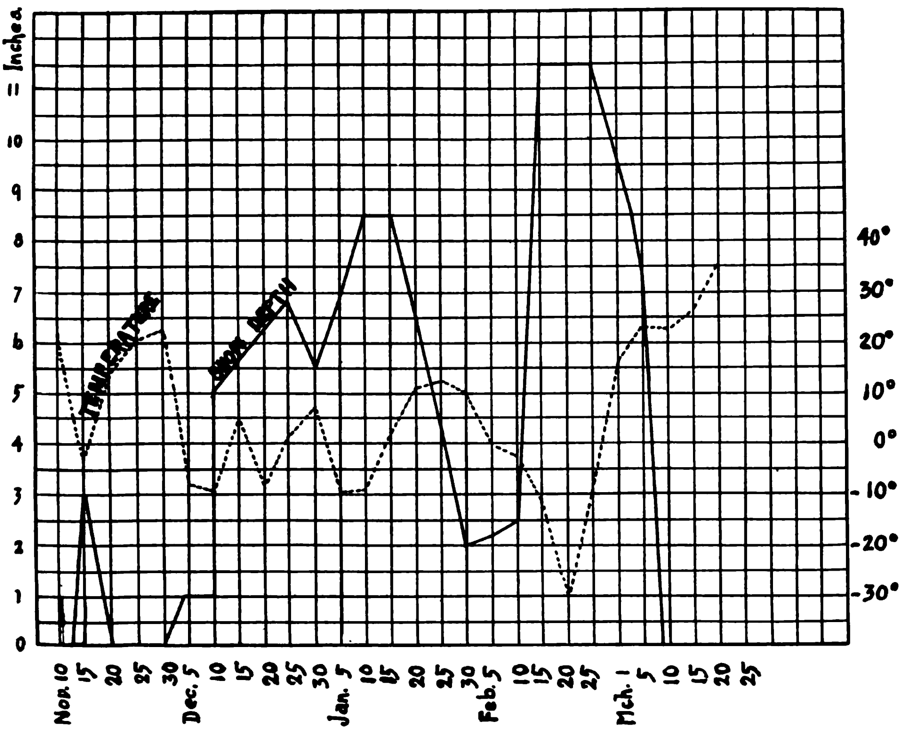

CHART I

Solid line shows depth of snow in inches during winter of 1909-1910 at 5-day intervals. The broken line shows the 5-day means of the minima temperatures centering around the dates indicated.

Alfalfa Losses in 1908–09 and 1909–10.—A brief summary of the losses undergone by the alfalfas during the two winters concerned is given in Table 1. In this table the row number, showing the order of planting in the plat, the accession number, and also the source of seed are given. To indicate the efficiency of the results the number of the plants involved are given for each year. The absolute loss of the plants from the hills and the drills are combined, and each year is given separately.

TABLE 1.—*Number, source, and data as to winter injury and seed-bearing capacity of alfalfa strains at Dickinson, North Dakota.*

Row No.	Accession No.		Source.	Number of plants involved, 1908-09.	Per cent winter-killed, 1908-09.	Number of plants involved, 1909-10.	Per cent winter-killed, 1909-10.	Per cent damaged and killed.	Average weight of seed per plant, 1909, in grams.
1	SPI	21329	Deseret, Utah (2nd crop, irrig.)......	88	92.0	7	71.4	94.3	16.0
2	SPI	21232	Mongolia (bulk lot)..................	85	23.5	67	17.9	55.4	16.8
3	PLH	2124	Mongolia (large seed)................	81	40.7	41	4.9	55.9	13.4
4	PLH	2125	Mongolia (medium-sized seed)........	83	37.3	46	2.2	57.2	11.5
5	SPI	12784	Emery, Utah..........................	81	85.2	9	67.0	87.8	12.4
10	SPI	21828	Deseret, Utah (1st crop, irrig.)	84	90.5	11	81.8	97.3	30.5
12	SPI	13237	Chinook, Mont........................	92	81.5	12	83.3	98.3	42.2
14	SPI	3507	Buenos Aires, Argentina.............	88	98.9	1	100.0	100.0	10.0
16	SPI	12549	Buenos Aires, Argentina.............	93	98.9	1	0.0	40.0	56.0
17	PLH	3321	Baden, Germany......................	85	75.3	18	72.2	86.7	25.0
19	SPI	12409	Diamond Fork, Utah (non-irrig.) ..	87	96.6	3	33.3	76.7	37.3
22	SPI	21867	Nephi, Utah (dryland).............	84	95.2	5	80.0	92.0	22.4
24	SPI	12695	Poitou, France......................	84	95.2	4	25.0	50.0	42.0
26	SPI	13259	Milburn, Nebr.......................	83	86.7	10	40.0	75.0	22.4
27	SPI	13857	Simbirsk, Russia....................	62	79.0	12	33.3	58.4	18.7
28	SPI	991	Tashkent, Turkestan.................	64	90.6	6	33.2	46.7	37.3
29	SPI	9359	Erivan, Russia......................	62	88.7	7	14.3	40.0	16.0
30	SPI	9450	Askhabad, Turkestan................	46	89.1	4	25.0	52.5	21.0
31	SPI	9452	Karabulak, Turkestan	66	68.2	20	5.0	38.5	16.8
32	SPI	9453	Bokhara, Turkestan.................	82	56.1	33	3.0	43.1	15.2
33	SPI	13999	Tashkent, Turkestan................	76	98.7	1	0.0	50.0	12.0
34	SPI	14786	Tashkent, Turkestan................	78	77.0	15	6.7	38.7	16.9
35	SPI	18425	Commercial, Turkestan.............	59	93.2	3	66.7	96.7	4.7
36	SPI	18751	Commercial, Turkestan.............	68	54.4	27	44.4	72.2	8.3
37	SPI	19968	Samarkand, Turkestan..............	56	64.3	17	58.8	84.7	16.3
38	SPI	20437	Tashkent, Turkestan................	77	89.6	7	100.0	100.0	12.0
39	SPI	21032	Commercial, Turkestan	72	36.1	42	30.9	61.9	16.1
40	PLH	3252	South Dakota (Tashkent, Turkestan).........................	75	9.2	62	3.2	42.9	8.8
41	SPI	12747	Billings, Mont......................	71	43.7	38	39.5	66.1	11.8
42	SPI	13436	Canada..............................	79	39.2	41	21.9	48.3	14.0
43	SPI	21247	Canada..............................	62	51.6	26	38.5	60.8	12.9
44	SPI	11651	Pueblo, Mexico.....................	62	89.1	7	85.7	95.7	8.0
45	SPI	11652	Guanajuata, Mexico.................	63	80.9	16	37.5	62.5	12.4
46	SPI	11275	Commercial (bought in Chicago)....	73	79.4	15	40.0	69.3	14.9
47	SPI	12398	Fort Collins, Colo..................	72	86.1	9	66.7	87.8	9.3
48	SPI	12671	Lawrence, Kan......................	66	84.8	9	55.5	85.6	37.3
49	SPI	12816	Chinook, Mont......................	79	70.9	19	78.9	92.6	35.5
50	SPI	12820	Clearwater, Nebr....................	75	66.7	20	30.0	66.5	25.3
51	SPI	21938	Excelsior, Minn. (Grimm)...........	71	7.0	64	3.1	26.7	20.1
52	PLH	3235	Fargo, N. D. (Grimm)...............	70	2.8	64	1.6	17.8	23.7
53	SPI	21945	Sextorp, Nebr. (dry land)	74	75.7	16	50.0	71.9	21.0
54	PLH	3251	Highmore, S. D. (Baltic)...........	78	34.6	45	15.5	32.9	42.5
55	PLH	3255	Nephi, Utah (dry land).............	79	84.8	9	66.7	87.8	25.0
56	PLH	3256	Nephi, Utah (dry land).............	82	86.6	8	62.5	85.0	42.0
57	SPI	21187	France (commercial sand Lucerne)..	81	63.0	27	29.6	63.7	29.1

TABLE 1.—Continued.

Row No.	Accession No.		Source.	Number of plants involved, 1908-09.	Per cent winter-killed, 1908-09.	Number of plants involved, 1909-10.	Per cent winter-killed, 1909-10.	Per cent damaged and killed.	Average weight of seed per plant, 1909, in grams.
58	SPI	21217	Germany (commercial sand Lucerne)	76	67.1	23	34.8	70.9	22.7
59	SPI	21269	Germany (commercial sand Lucerne)	75	88.0	8	0.0	35.0	56.0
60	SPI	20896	France (commercial sand Lucerne)...	78	89.7	5	20.0	88.0	22.4
61	SPI	22416	Piedmont, Italy......................	76	98.9	1	0.0	30.0	
62	SPI	22417	Germany (Provence strain)..........	82	98.8	1	100.0	100.0	28.0
63	SPI	22418	Germany (commercial sand Lucerne)	83	86.6	8	50.0	90.0	30.5
64	SPI	22558	Gunnison, Utah, (irrigated)..........	82	89.0	8	62.5	81.3	42.3
65	SPI	22559	Gunnison, Utah, (dry land).........	70	94.3	4	50.0	72.5	28.0
66	SPI	12803	Setif, Algeria.........................	81	79.0	14	14.3	53.6	20.0
67	SPI	20988	Commercial Turkestan...............	79	50.6	34	0.0	27.1	13.2
68	PLH	3346	Richardton, N. D....................	62	90.3	6	50 0	81.7	18.7
			Average....................................		72 7	.....	39.4	....	19.9

In 1910, in addition to the mere determination of the number of dead plants, the living plants were graded, the grades ranging from 1 to 10. A plant just persisting through the winter and showing a small amount of vitality was given the lower grade while a plant of maximum growth and vitality was given the maximum grade. This sliding scale method, combined with the absolute loss, gives us a series of means indicating the loss and damage sustained by any strain. Seed was harvested from the various strains in 1909 and the average amount of seed per plant is also given in this table. The loss and damage data for the table were taken during the first decade of June for each year.

An examination of Table 1 shows on the whole a very heavy loss for the first winter. If each strain or row be regarded as a unit, then the average loss of the strains amounted to 72.7 per cent. These losses have been discussed in detail in Bureau of Plant Industry Bulletin No. 185, and need not be dwelt upon here. But it is desired to call attention to Rows 51 and 52, comprising the Grimm alfalfa. The average loss for these two rows amounted to less than 5 per cent as against an average of 77.5 per cent for the entire nursery. A few of the other rows appeared reasonably hardy, especially Row 40, P.L.H. No. 3252. This was originated in South Dakota by Prof. W. A. Wheeler, the original seed being a portion of S.P.I. No. 991, introduced

from Turkestan by Prof. Hansen. Aside from a few striking exceptions, the losses of the first winter ran remarkably high.

Loss During the Second Winter.—From the very nature of things, but comparatively few plants could be dealt with during the second winter, in case of nearly all of the rows. The probable errors are therefore larger for the per cents obtained during 1910. But the large probable errors are offset in great measure by the general uniformity of the results secured in the various rows. In short, the effect is cumulative.

If, in this case, each strain be considered as a unit, we find the average winterkilling of the whole nursery to be 39.4 per cent. Considering the fact that the second winter was physiologically mild, so mild that red clover suffered practically no killing and radically milder than the first winter of the experiment, it may be worth while to inquire into the possible causes of the comparatively heavy killing of the second winter. One might suppose that all of the tender plant would be killed during the severe winter and that during the second, mild winter, the killing would be practically nil.

The Relation of Killing During the First and the Second Winter.—In order to show the relation of the killing of the various strains for the two winters, Table 2 is presented, which shows the correlation existing between the killing of the first and the second winter. There is seen to be rather a strong positive correlation and of a skew character. This skewness is brought about by the fact that no strain had a larger percentage killed during the second winter than during the first winter.

There are two minor exceptions to this in Rows 38 and 49. A few strains that killed badly during the first winter showed a relatively high percentage of killing the second winter, but in some rows the heavy killing of the first winter was followed by but little loss the second winter. This might indicate that in such strains the few surviving plants represented lines of hardiness. Plantings in a following generation would be necessary to prove this point.

Relation of Seed Production in 1909 to Loss the Second Winter.—A study of this factor is of evident importance. It is quite conceivable that the heavy seed production in certain strains in 1909 so reduced the vitality of the plants that their chances to live through the winter were much reduced. In this case, unfortunately, we do not have the seed-bearing record of each individual plant, except in a few instances. In some rows, at least, the plants that died may have been the heavy producers of the row, while those that persisted may have borne little seed.

Before this relationship is presented, it will be well to see if there is

TABLE 2.—*Correlation in Alfalfa.*

1908–09 Per cent of plants winter killed—subject.	1909–10 Per cent of plants winter killed—relative. 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	
5	1																				1
10	2																				2
15																					0
20																					0
25				1																	1
30																					0
35				1																	1
40	1				1		1														3
45	1							1													2
50	1																				1
55								1	1												2
60	1																				1
65						1						1									2
70	1					1	1														3
75															1	1					2
80		1	1				1	1		1											5
85								1				1		2			1				5
90	1		1	1	1			1		2			2	1			1			1	12
95					1		1			1				1	1	1	1				7
100	3						1													2	6
	12	1	2	3	3	2	5	5	1	4	0	2	2	4	2	2	3	0	0	3	56

NOTE.—Per cent of plants per strain killed in winter 1908–09, subject; per cent of plants per strain killed in winter 1909–10, relative. Coefficient of correlation, 0.35 ± 0.08

TABLE 3.—*Correlation in Alfalfa.*

Number of plants in row.	Weight of seed in grams per plant. 5	10	15	20	25	30	35	40	45	50	55	60	Totals.
5	1	1	1		3	2		1	1			1	11
10		2	2	3	2		1	2	2			1	15
15			1	3			1		1				6
20			1	2	2	1		1					7
25					1								1
30		1	1			1							3
35			1	1									2
40			1										1
45			2	1					1				4
50			1										1
55													0
60													0
65		1			2								3
70				1									1
Totals..	1	5	11	11	10	4	2	4	5	0	0	2	55

NOTE.—Number of plants per row in 1909 subject, average weight of seed in grams per plant in 1909 relative. Coefficient of correlation,—0.22 ± 0.09.

any connection between the number of plants per row in 1909 and the average weight of seed per plant, for the same season, for the rows concerned. Table 3 is presented, which shows a negative correlation to the extent of 22 per cent which indicates that on the whole, those rows that have the least number of plants are the ones that produced the largest amount of seed per plant. This fact involves several points.

The thinner rows had more room to develop and more available moisture, which may have been important factors in seed production. Upon the other hand it would be only reasonable to suppose that those rows having the fewer plants had also less average vitality per plant than those rows receiving the least injury during the previous winter. Upon this basis we would hardly suspect the weak plants to be the heavy seed producers. They of course might have had a chance to recover from their weakened condition, but even then we would hardly think of their surpassing the stronger plants. The theory that the weaker plants produced the larger amount of seed because of their weakness seems scarcely tenable. Plants under hard conditions may produce seed as a last resort, but the amount produced in such cases is relatively small.

TABLE 4.—*Correlation in Alfalfa.*

Average weight of seed per plant in grams.	Number of plants killed per row.																				Totals.
g. per plant.	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	
5														1							1
10	1								1					1			1			1	5
15	4				1			4						1						1	11
20	2	1	2	1			2			1		1			1						11
25	2			1	1		1	1		1				1	1	1					10
30						2				1										1	4
35										1							1				2
40							2					1				1					4
45				1	1								2				1				5
50																					0
55																					0
60	2																				2
Totals..	11	1	2	3	3	2	5	5	1	4	0	2	2	4	2	2	3	0	0	3	55

NOTE.—Average weight of seed per plant in 1909, subject; number of plants killed per row in 1909–10, relative. Coefficient of correlation essentially zero.

Table 4 shows the correlation existing between the average weight of seed per plant as harvested in 1909 and the winterkilling undergone by the various strains during the winter of 1909–10. The coefficient

of correlation was determined and found to be essentially zero. But an examination of Table 1 shows that in some 'nstances one would be led to suspect a casual relation existing between seed production and winterkilling. Table 5 gives instances of this period only.

The killing undergone by these rows the second winter indicates plainly that these rows were tender after seed production. Tenderness of the strains as a whole is indicated by the amount of killing experienced by the rows the first winter. One is tempted to believe that these rows were weakened to some extent by abundant seed production in 1909, perhaps to an extent that affected their ability to withstand even a mild winter. We may be reasonably certain that in the rows cited each plant produced a reasonable abundance of seed, as the average amount of seed per plant is so high.

But it is possible to find rows that show quite reverse conditions. Row 59, commercial sand lucerne, suffered a loss of 88 per cent the

TABLE 5.—*Relation of seed production to winter killing.*

Row No.	Source.	Weight of seed per plant in grams 1909.	Killing in 1909-10.	Killing in 1908-09.
10	Deseret, Utah (irrig.)	30.5	81.8	90.5
12	Chinook, Mont.	42.2	83.3	81.5
48	Lawrence, Kan.	37.3	55.5	84.8
49	Chinook, Mont.	35.5	78.9	70.9
56	Nephi, Utah (dry land)	42.0	62.5	86.6
64	Gunnison, Utah (irrig.)	42.3	62.5	89 0

first winter and had 8 plants left over. These 8 plants bore on the average 56 grams of seed per plant. None of the plants died the second winter and they showed a grade of 65 per cent in June, 1910. Row 54, the Baltic alfalfa, is also an outstanding example. This showed a killing of 34.6 per cent the first winter. In 1909 the 45 plants had an average seed production of 42.5 grams. The loss during the second winter was but 15.5 per cent.

Relation of Thickness of Stand to Winterkilling.—As pointed out in the previously cited bulletin, the thickness of stand may be a potent factor in bringing about loss through cold. A thick stand of plants tends to deplete the ground of moisture; thus the tissues of the plants have a chance to dry out during the fall and to get into a mature condition for the winter. The plants in the thin stand have more moisture and thus will keep on growing in the fall. Being full of sap and in an active condition at the onset of cold weather, the plant is in a poor way to resist injury. In this instance, however, the plants in

FIG. 1. THE ALFALFA NURSERY SOWN IN 1908, AS IT APPEARED JULY 4, 1910.

The two rows of Grimm, and the Baltic alfalfa to the left, show up in the foreground. The Mongolian is at "1," and the Turkestan alfalfas are at "2" and "3" in the middleground.

even the better stands had a good chance to obtain moisture as in most cases the rows on either side of a good row were more or less vacant.

The Condition of the Plant after the First Winter.—While the major portion of the plants made a very good growth during the second season, including many of the plants that were later killed during the physiologically mild winter of 1909–10, yet many of the plants may not have been healthy. An alfalfa nursery was planted at the Dickinson station in the spring of 1909 which was not thinned until the spring

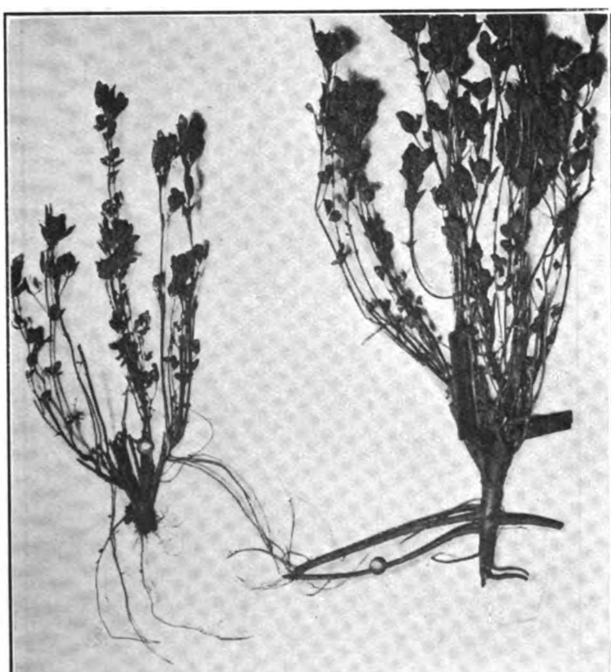

FIG. 2. TWO PLANTS FROM THE ROW OF HUNGARIAN LUCERN NO. 25179, PLANTED IN 1909. The roots are badly injured after the mild winter of 1909–10.

of 1910. The extra plants were cut out with a spade. With the exception of a few rows of South American and Australian alfalfas, the winterkilling in the nursery was markedly low. This was not surprising, considering the nature of the winter. In certain rows the actual killing did not amount to much, but the thinning revealed a good many plants that had roots rotted off. These rotted roots appeared most abundantly in weaker rows. Figure 2 shows 2 plants of Hungarian lucerne, S. P. I. 25179, with the taproots rotted off. Both of these

plants made a fair growth in 1910 considering the crowded condition and the dryness of the season. The larger plant made a recovery of 14 inches in 2 weeks after first cutting.

With a favorable season, such as occurred in 1909, it is quite reasonable to suppose that the larger plant in figure 2, growing in a nursery,

FIG. 3. PLANT FROM UTAH ALFALFA NO. 21823.
Planted in 1908; dug and photographed July, 1910. Plant weak and roots badly rotted.

would give a good account of itself. But after a season's growth and after medium or heavy seed production it would be in a poor condition to withstand the rigors of a winter. The first cold snap might kill the plant.

The theory is rendered all the more probable by a study of some of the plants in the 1908 nursery, still living in 1910. Figure 3 shows

a plant dug from Row 10, Utah alfalfa, on July 12, 1910. It did not have a vigorous top, and a study of the root system explains this. The upper 3 or 4 inches of the taproot are diseased, but the two laterals are apparently healthy. That portion of the taproot below the laterals is quite healthy except at its upper portion. Here it is badly

FIG. 4. PLANT OF COMMERCIAL AND LUCERN No. 22418.

Planted in 1908; dug and photographed July, 1910. Plant full of pods, but root system in very bad shape.

diseased and indeed is nearly rotted away from the main portion of the plant. This would have taken place before the end of the season and then the plant would have had but two laterals and but very few feeding roots. The plant would have had a poor chance the winter following.

An even more pronounced case is shown in figure 4. This plant is from Row 63, commercial sand lucerne from Germany. The plant had a small top but it had blossomed and was well filled with seed pods. A portion of the 1909 crown had winterkilled. This is shown separately in the figure. The living portion had really no organic connection with the old crown at time of digging. A bunch of roots

FIG. 5. ONE OF THE WEAK PLANTS FROM GRIMM ALFALFA; P.L.H. 3235, SEED FROM FARGO. Considerable of the top not shown. Upper portion of tap root a little diseased, but in the main healthy.

is shown at the left; their proximal ends are above. It can be seen that these ends are quite rotten. They were evidently attached to the plant at some time during 1910 but had rotted off prior to the time of digging on July 12. The major portion of these roots is apparently healthy. That portion of the taproot shown detached was all but rotted away from the plant at time of digging. Only a few strands of

tissue and a slight amount of cortex held it. It would have been entirely off in a few days. The portion of the taproot shown attached to the plant was more or less diseased. A few small feeding roots are shown at the right, almost the plant's sole dependence at time of digging. It is doubtful if the plant could have persisted until the close of the season and it could not have lived through the winter. Diggings of some of the other plants in the nursery showed similar conditions.

Figure 5 shows one of the weakest Grimm plants from Row 52. This has some diseased tissue at the upper portion of the taproot but it is in far better condition than the plants shown in figures 3 and 4 and probably its chances were good for persisting several years.

It is extremely probable that many of the plants in the 1908 nursery that survived the severe winter of 1908–09 were in a condition similar to the plants shown in figures 3 and 4 during the season of 1909. Their doom was already sealed and only moderately severe conditions were necessary to kill them entirely. At least some of the factors that have been discussed previously probably had some influence in their taking off but the fatal thrust had been received the first winter.

Comparison of Various Strains.—It is interesting to compare the spring conditions of some of the strains, including in this condition the loss of the previous winter. The following summary shows the grading of a few of the strains:

TABLE 6.—*Variants of a number of strains.*

Classes.	Number of nursery rows.						
	40	51	52	54	57	58	67
0	2	2	1	7	8	8	0
1	3	0	0	0	2	1	0
2	1	0	0	0	1	1	0
3	4	2	1	1	1	3	3
4	3	6	1	1	6	2	4
5	13	5	2	2	2	3	2
6	15	5	3	5	0	3	1
7	7	9	8	5	3	2	5
8	9	7	16	5	1	0	5
9	1	15	13	10	2	0	8
10	4	13	19	9	1	0	6
Totals....	62	64	64	45	27	23	34

Class O includes dead plants; Class 1 included the very weak plants while Class 10 includes the strongest plants. Row 40 is of South Dakota-Turkestan origin, Rows 51 and 52 are of the Grimm alfalfa, Row 54 is the Baltic, Rows 57 and 58 are commercial sand lucernes,

coming from France and Germany respectively, and Row 67 is commercial Turkestan.

If the above variants are computed to the same numerical basis and the curves slightly smoothed, we will have the following series of numbers:

TABLE 7.—*Variants of table 6 computed to the same numerical basis.*

Classes.	Number of nursery rows.						
	40	51	52	54	57	58	67
0	3.2	3.4	1.9	15.9	26.3	31.2	0
1	4.2	1.7	0.9	7.9	16.3	17.3	0
2	3.2	0	0	0	4.9	3.8	0
3	4.2	1.7	0.9	1.1	3.3	7.6	9.2
4	6.0	6.8	1.9	2.3	11.5	9.5	10.7
5	13.2	9.3	2.8	3.5	13.1	9.5	9.2
6	23.4	8.5	4.8	7.9	3.3	11.6	4.6
7	17.0	12.0	10.0	11.4	4.9	9.5	9.2
8	13.0	13.7	21.6	11.4	6.6	0	15.4
9	8.4	18.9	26.2	17.1	4.9	0	20.1
10	4.2	24.0	29.0	21.5	4.9	0	21.6
	100.	100.	100.	100.	100.	100.	100.
Means of unreduced data in per cents	57.1	73.3	82.2	67 1	36.3	29.1	72.9
Per cent killed first winter	9.2	7.0	2.8	34.6	63.0	67.1	50.6
Per cent killed second winter	3.2	3.1	1.6	15.5	29.6	34.8	0

The results appear so plainly in the columns that it is not necessary to plot the different rows on cross-section paper as could easily be done. There are included in the above summary the hardiest strains of alfalfa in the nursery, with the exception of the 3 Mongolian rows.[b] Two of the above rows, Rows 57 and 58, are not particularly hardy but much interest centers around the sand lucernes. These rows showed some indications of hardiness for the first winter, but the killing suffered by them the second winter is nearly as high as the average killing of the entire nursery.

It is quite evident that Row 52 is best of all those under experiment. This is seen to have killed least the first winter. While every effort was made to give an unbiased grading to plants of different rows, in this particular case the origin of this row was not known until after grading.

Mr. Charles J. Brand was the senior author of a previous report upon this experiment, and it is to him that much of the planning of the work is due.

[b] The Mongolian Alfalfas were partly covered with dirt in a heavy rain in 1909 and the spring grading of 1910 was thought to be scarcely fair to them.

WHAT SEED SELECTION AND BREEDING HAVE DONE FOR TOBACCO IN CONNECTICUT

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A study of the statistics of the Department of Agriculture shows that the Connecticut Valley is one of the most important tobacco producing regions in the United States. According to this report there were only five states in 1909 which had a greater farm value for tobacco than Connecticut.[a] These states are Kentucky, North Carolina, Virginia, Ohio and Tennessee. If, however, we consider the average acre value, Connecticut easily heads them all. It is also true that no section in the United States produces wrapper leaf of so high a quality as Connecticut.

"What seed selection and breeding have done for tobacco in Connecticut" may be discussed under the following heads:

(1) What has been accomplished by seed selection. (2) The making of new types by hybridization.

In discussing the subject "What has been accomplished by seed selection," let us consider what is understood by the word selection. It is an acknowledged fact that among both plants and animals no two individuals are exactly alike. Variation is the rule instead of an exception to the rule. There are two main kinds of variation.

(1) Fluctuating variations, such as size of leaf, height and weight of plant, which are due to different conditions of fertility, or to better position for development. Such fluctuations are not inherited.

(2) Inherited variations, which may be either large or small, but are caused by some difference in the factors of inheritance and are entirely independent of surrounding conditions for their transmission although favorable environment is often needed for their full development.

Perhaps the best work of modern experimentalists, which has proved the truth of this classification, is that of Johannsen (1909), a Danish plant physiologist. He used the bean plant for his work and found that a single commercial variety was in reality composed of different and distinct types, which could be separated from each other by self-pollinating the different plants by hand and studying their progeny. For example, he investigated the character weight as applied to individual beans and found that progress could be made when larger beans

[a] Yearbook of the United States Department of Agriculture, 1909, p. 515.

were selected from the *mixed commercial variety* for several generations; but that where a single type had been isolated by self-pollination it made no difference whether larger or smaller beans were selected from that type for the next year's seed. In either case the progeny were true to the type.

As further evidence that fluctuating variations are not inherited, the following results are given.

From potato tubers grown originally from a single potato, East (1908, 1909), at the Connecticut Agricultural Experiment Station, selected and planted tubers having a high percentage of protein and others having a low percentage. He proved that this character of high or low protein however, was not inherited. That is, on the average, the progeny of tubers with high protein was no richer in protein that that of tubers with low protein.

Jennings (1908), in his investigations on a small one-celled protozoan animal which propagates for hundreds of generations by simple division, found that by selection he could divide his individuals into a number of pure races, but after they were isolated no change could be made by a selection of larger or smaller individuals.

The following statement made by Pearl and Surface in Bulletin 166 of the Maine Agricultural Experiment Station, sums up our present idea of selection: "There is a rapidly accumulating mass of evidence that the chief, if not the entire, function of selection in breeding is to isolate pure strains from a mixed population. It is found impossible to bring about by selection improvement beyond the point already existing in the pure (isolated) strain at the beginning."

Pearl's (1909a, b) own work on selection in poultry supports this view. He selected individuals which gave a high egg production for many years, but was unable to obtain from a single pure line a strain which would produce a greater number of eggs than the pure line itself. To sum up our present belief, the only reasonable aim in selecting to improve the yield or other qualities of plants and animals is solely to identify and isolate those types already existing which have the greatest promise from the business point of view.

This conception then is what one must apply when inquiring what has been done or what can be done by selecting tobacco seed.

Because of our lack of knowledge of the characters of tobacco which were formerly grown in Connecticut, it is impossible to say how much, if any, the Connecticut Havana Seed and Broadleaf varieties have been improved by selection. It is quite likely however that considerable progress has been made in isolating types, both consciously and

unconsciously, by the tobacco growers, for all of these commercial varieties are composed of numerous types, as has been shown by the work of the Bureau of Plant Industry. Bulletin 91 tells of the isolation of 29 different types from one commercial field of 46 acres. Each bred true the following year. Even in my own experience, this has been clearly proved. When about the age of fifteen, it was first brought to my notice on our home farm, that our Havana Seed was composed of different strains. The year in which this was noticeable was one in which a portion of our tobacco plants was purchased from farmers situated in different parts of the town. Through one field of tobacco there was a roadway. On the northern part of the field the plants used for setting were purchased; on that part of the field south of the roadway our own plants were used. After the tobacco was grown the difference between the northern and southern plats was so noticeable that any tobacco grower on entering the field would see it at once. The tobacco on the southern plat had a narrow, pointed leaf, while that on the northern had a much wider leaf and was fine-shaped to the very tip. Seed was saved from this type, which bred true the following year.

The isolation of different types of tobacco is easily accomplished, since the tobacco flower is naturally arranged for self-fertilization. In order to be sure that no crossing takes place the seed should be saved under a Manila paper bag. The seed head should be bagged before any of the blossoms have opened, and about every ten days the bag should be removed and the dead material thrown out. If only about half as many pods as usually grow from one head are allowed to form, the seed will mature earlier and be in better condition. Tobacco, unlike corn and other naturally cross-fertilized crops, can be inbred many years without deterioration.

The most notable results of such work from a commercial standpoint have produced a wrapper leaf tobacco the equal of almost any, our Cuban shade variety.

The history (Stewart, 1908) of the production of cigar wrapper tobacco under shade in the Connecticut valley is well known to many of our tobacco farmers. This method originated in Florida in 1896. In 1900 the officials of the Connecticut Experiment Station and of the Bureau of Soils, of the U.S. Department of Agriculture, in coöperation grew one-third of an acre of tobacco under shade in Connecticut, from Florida Sumatra seed. This tobacco, when fermented, assorted, and packed, brought 72 cents per pound.

In 1901 the coöperative agreement between the Connecticut station

and the Bureau of Soils was discontinued and each worked along its own lines. This year 41 acres were produced under shade, the Bureau of Soils furnishing experienced men to instruct the farmers in methods of cultivating, harvesting, and curing the crop. About 300 bales of this tobacco were produced, and in order to place it on the market as soon as possible the tobacco was sold at public auction in Foot Guard Hall, Hartford, Conn., to the highest bidder. The prices paid were very satisfactory and were as high in some cases as $2.65 per pound, thus giving the grower $1000 an acre above expenses. The results of this sale were taken as bona fide evidenceof the success of the industry in Connecticut, and the shade acreage in 1902 was increased from 41 acres to more than 700. Seed was purchased indiscriminately from Florida at the high price of $2 an ounce. The year 1902 was a cold, wet season. The farmers did not know the correct methods to pursue in growing, curing, or packing shade tobacco, and with inferior seed the result was a disastrous failure. The results the following year were even more unfavorable, the industry being accounted a failure and the cause of heavy financial loss.

This apparent failure of shade tobacco illustrates the necessity of a knowledge of the laws governing plant introduction and variation, and shows that, before a new crop or type is grown to any extent, careful breeding work should be pursued by some person who has a knowledge of these laws and of the methods of culture of the crop.

In 1903 the attention of the Bureau of Plant Industry was called to the failure of shade tobacco in Connecticut and as the Department of Agriculture had much to do with promoting the industry it was thought necessary to do everything possible to determine the cause of failure and remedy it.[b] This summer, while at the Olds & Whipple plantation, in Bloomfield, about 200 plants from imported Cuban Seed were observed. Of these only 5 or 6 were apparently of any value. In counting the number of leaves the range was from 7 to 21 per plant, and apparently there were three classes, one in which the mode was 8, one with the mode at 16, and one at 19, the mode being that class with the greatest number of individuals. This is shown below:

Leaves per plant..	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Variates	1	3	7	4	4	3	1	4	8	14	16	10	18	27	9	

[b] Recent experimental results have convinced the writer that a transportation of seed from a warmer to a colder climate does not cause a breaking up into types. We now know that imported Cuban Seed, due to the methods of handling seed in Cuba, is in reality a mixture of many types and the breaking up above alluded to is simply an expression of the different hereditary qualities of the parent seed plants.

The method used in the improvement of this shade tobacco was the row method. Seed was saved under bag from desirable field types, the leaves being picked from each seed plant and saved separately and tagged with the same selection number as the seed. After curing, the plants were examined and those which seemed to be of any value were grown the following year. In a crop in which weight is not of the greatest importance, but uniformity and quality are absolutely necessary, it was found that selecting the plants in the field without regard to quality after curing and fermenting did not give a correct idea of the value of the selection. Seed from desirable field plants, which gave promise of value after curing, was used for the next year, a row being grown from each selection. The same method was used this year as in the previous one, and those plants which were not used for seed from each row were harvested, fermented, and assorted, to give an idea of the value of the selection.

Among the types tested which gave promise of commercial value were two Sumatra and two Cuban types. The Sumatra types gave a much greater percentage of light wrappers, but the tobacco when fermented was of a very papery texture.

A type known as the Hazlewood strain of Cuban, which gave a yield of 1210 pounds per acre and assorted out only 235 pounds of light wrappers, proved to be a very valuable tobacco, because the quality was such that it could be used on a high-grade cigar with satisfaction. It was tested along with other selections in 1906 and gave a greater yield than the previous year, without any deterioration in quality.

In 1907 three acres were tested commercially. The results of this test and the discussion of the production of cigar wrapper tobacco under shade in the Connecticut valley, may be found in Bulletin 138 of the Bureau of Plant Industry, by J. B. Stewart. Suffice it to say that 500 acres of shade tobacco were produced in the Connecticut valley for the year 1910, and present indications lead to the belief that the acreage will be greatly increased the coming year. Several of our large plantations have purchased more land and intend to raise much more shade tobacco in 1911.

The problems of tobacco selection, then, as has been shown, are the isolation of desirable types from the field and using seed from those types which when tested prove of highest value. Because the tobacco plant is so noticeably affected by conditions of fertility and differences of soil, the selection of a desirable type which will breed true is not so easy as it would seem. It is necessary to make a number of selections

from desirable types and grow the following year those which appear to breed true to the type desired.

The Making of New Types by Hybridization.—The earliest work of a practical nature which was based on the principle of crossing two plant varieties is that of Thomas Andrew Knight, who is looked upon by many as the father of plant breeding. In 1806 Knight said: "New varieties of every species of fruit will generally be better obtained by introducing the farina of one variety of fruit into the blossoms of another than by propagating from any single kind."

Since the time of Knight the improvement of our cultivated plants has in large measure been by hybridization, nearly all of our cultivated varieties, with the exception of our cereal crops, having been produced by the method.

In 1903 a number of crosses were made between different varieties of tobacco which were then being grown in Connecticut, with the hope of producing new varieties which would prove more valuable than the Connecticut Havana Seed and Broadleaf.

The technical work in crossing two varieties of tobacco is very simple. The tobacco flower is so large and easy of manipulation that it is a very easy matter to make a cross between two varieties. Before the blossom opens the corolla is split up one side and the stamens removed. Pollen from another variety is taken from its stamens, by means of a scalpel or other sharp instrument, and applied to the pistil of the variety which has been emasculated. Those blossoms not used in crossing are removed and the seed head covered with a Manila paper bag.

Among the crosses made was one between Havana Seed and Sumatra. The Havana Seed used was the ordinary variety grown in Connecticut, which has an average of from 16 to 23 leaves per plant and grows to a height of 5 to 7 feet; the Sumatra was the small-leaved type, which averages from 24 to 31 leaves per plant and grows 8 or 9 feet tall. The first generation of this cross, which was grown in 1904, had a uniform habit of growth, but grew a little more luxuriantly than either parent. In 1905 the cross broke up into Havana and Sumatra types, the Havana type being dominant, although the exact ratios are unknown. Seed from the Havana types were grown for planting in 1906.

That year the Havana type again broke up into different kinds of plants. One plant appeared which had the habit of growth and appearance of Havana, but it had 26 leaves. This plant was bagged and seed used for a row test in 1907. All of the progeny were uniform

in habit in 1907. The entire row was topped, however, by mistake, only a little seed being saved from a late plant for the next year's test. In 1908 the seed from the late plant and that seed not used in 1906 was sown, about one-third of an acre being grown. This new strain had a uniform habit of growth and was named the Halladay Havana, in honor of the man on whose farm it originated. One hundred seed plants were saved this year and, after the leaves were cured, were examined and those selections which excelled in quality and grain were grown in 1909. The remainder of the field grown in 1908 was harvested, assorted and fermented and proved the best of any of the new outdoor varieties tested.

In 1909 about an acre of the best selections were grown in Connecticut and three acres were grown by Massachusetts farmers, under the supervision of the tobacco experts stationed in the Connecticut valley, the Hatch Experiment Station furnishing necessary funds for the tests. The results were very favorable. In all cases the tobacco brought as much a pound as the Havana Seed grown under the same conditions. On the Arnold farm in Southwick a measured acre, when sold, brought over $700 without doubt the largest sum received in recent years for an outdoor acre of tobacco. The Halladay Havana has produced as high as 3300 pounds from one acre, over 50 per cent more than is ever obtained from our other varieties. Besides the tests mentioned, about 25 acres were grown in 1909 by Connecticut valley farmers, seed being furnished from the 1908 selections. When primed the quality of many of the leaves was excellent, but the tobacco lacked uniformity. It is perhaps too soon to say positively that the Halladay Havana will supersede our Connecticut Havana Seed, but the outlook is very favorable for its success. This year over 125 acres have been raised, the tobacco looking very much better in the field than it did last year.

The production of a new variety by hybridization is in some measure a game of chance, perhaps, as has been stated by Stewart, who produced the Halladay Havana, but the work of investigators in variation and heredity during the last few years indicates that when two varieties are crossed certain results may be expected. The Halladay Havana strain was considered to be a mutation, or sport, but a knowledge of the parent varieties and the known laws of inheritance show that the Halladay is the result of a recombination of parental characters. The rediscovery of Mendel's law of heredity in 1900 and the great interest among scientific workers and practical breeders since that time have had much to do with our present knowledge of hybridi-

zation. Time will not permit me to enter into this subject exhaustively, but the underlying law may be briefly illustrated as follows:

When a cross is made between two pure varieties as a rule the first generation is of a uniform nature, because each germ cell contains the same hereditary substance, the cross resembling in many characters one parent or the other. When resembling either parent in any character, that character is said to be a dominant one. The second generation, however, shows a splitting up into different types. What we really have is a recombination of parental characters. Those types which contain all characters in a pure or homozygous state, or which have received the same hereditary substance from both male and female, will breed true, while those which receive a certain character from only one germ cell are said to be in a heterozygous condition and will break up the next year into different types. The results obtained from crossing two varieties of corn illustrate this fact. When a white and a yellow corn are crossed we obtain the year the cross is made a yellow corn; the yellow color is a dominant one and covers up the white color, or absence of yellow, which is called a recessive character. The phenomenon of complete dominance is often not found as the F_1 generation may look like one parent in some characters, may be entirely different from either parent, or may appear as a blend between the two. The important fact of Mendel's law is the segregation of characters in the F_2 generation. What we really have is a recombination of parental characters which may be illustrated by the corn cross.

When we grow this crossed corn we obtain white and yellow kernels in the ratio of 3 yellow to 1 white. The white kernels will breed true to the white color the following year. If these two kinds of corn had differed in two characters instead of one, that is, for instance, if the yellow was a sweet corn and the white a flint, we would only receive on growing the cross one white sweet kernel in 16; that is, one kernel which had both characters recessive in 16 which would breed true. If then, we cross two varieties which differ in six separately inherited pairs of characters, we may expect to obtain in the second generation only one individual out of 4096 with all characters as recessive ones.

The data of the production of the Halladay Havana were turned over to the Connecticut Experiment Station in 1908 and a consideration of them proved without doubt that the Halladay was produced by a recombination of parental characters.

As we have already seen, the Havana parent of the Halladay grows to a height of 5 to 7 feet and had from 16 to 23 leaves per plant, while

the Sumatra (East, 1910)[b] grows to a height of 8 to 9 feet and averages 24 to 31 leaves per plant. If there were six separately inherited characters between the Havana and Sumatra, for the difference in the number of leaves one should expect only one plant out of 4096 in a pure state, which would have all these characters as recessive ones—a plant that would breed true in succeeding generations.

The first generation of the cross between Sumatra and Havana grew very similar to the Havana, and the second generation, in which we expect a breaking up into types, was composed of Havana and Sumatra types, although the factors were unknown. As no plant appeared this year with the number of leaves of the Halladay and as only about 3000 plants were grown, the nonappearance of a plant with the number of leaves of the Sumatra can be explained by the fact that not enough plants were grown to obtain one with all characters recessive. As this plant appeared the following year and bred true to type, the explanation used above is perfectly logical.

Work is now being carried on at the Connecticut Experiment Station, in coöperation with East, of Harvard University, to enable us to understtand just what may be expected from a cross between two varieties of tobacco, with the belief that, in order to accomplish the best results, it is necessary to know how the different characters of tobacco are inherited. A cross made last year which should give a strain valuable for the Broadleaf section and which was grown this year was one between Broadleaf and Sumatra. The selection had leaves of the Broadleaf type and all grew uniformly. If enough plants are grown next year we should obtain one with all the characters pure, combining the large leaf and texture of the Broadleaf with the number of leaves of the Sumatra. If this plant fails to appear, it will be because enough plants have not been grown to obtain the necessary recombination of characters.

The work of improving tobacco by hybridization should be by the following plan:

Only a few plants need to be grown of the first generation, as all will be similar and will not breed true. The second generation, however, should consist of from 5000 to 6000 plants, as this is the generation in which a breaking up into different types may be expected. This year seed should be saved from those types which give promise of value, and should be grown in two selections the following year. When a type gives promise of commercial value from the row test, a larger amount should be grown, and ,after being harvested, cured and fermented, should be tested for quality.

[b] In this article the variety known as Sumatra was called Cuban by mistake.

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TOBACCO BREEDING WORK IN MARYLAND

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Most of the original selections and hybrids were made in 1904 and 1905 by Messrs. Cobey and Brown.

The more important crosses were between the native Maryland tobacco and the Connecticut Broadleaf variety; and between the Maryland strains and White Burley.

Connecticut Broadleaf resembles Maryland tobacco somewhat in habits of growth but has a larger, broader, and rounder leaf. The hope in making this cross was to secure a strain having the characteristic texture and bright color of the best Maryland types and the superior leafiness of the Connecticut Broadleaf variety.

In the general appearance of the cured product Maryland tobacco and White Burley possess greater points of resemblance than any other distinct American varieties.

The Maryland plant, however, does not possess the characteristic chlorophyl modification of Burley as it grows in the field. Burley possesses the better color in the cured product. Color, next to good burning quality is one of the most sought after attributes of the

Maryland type of tobacco. The idea in making this cross between Maryland and White Burley was to improve the color of the Maryland tobacco while retaining its other characteristics and desirable qualities.

Other crosses were made, but certain strains of these two were the only ones showing any particular merit from the standpoint of the Maryland tobacco grower.

Since 1905 the tobacco breeding work in Maryland has consisted principally in testing the more promising carefully selected strains from these two crosses in competition with the very best and most carefully selected strains of a number of types of the native Maryland tobacco.

The most striking results observed in these tests, made at the Upper Marlboro substation, has been the increased vigor of growth and the leafiness of the hybrids, particularly that of the best strains of the Connecticut Broadleaf-Maryland hybrid.

The best of these hybrid strains from the Connecticut Broadleaf cross have out-yielded in each of several competitive tests, made during the past three years, any of the regular native strains by from 50 to 200 pounds per acre under identical conditions and on a well fertilized soil.

The quality of these hybrids aside from the increased yield has probably been at least as good as that of the regular Maryland types. Dealers on the Baltimore market have been rather inclined to hold the opinion that these hybrids were somewhat off from the true Maryland type of tobacco, but they were not able to substantiate this opinion with any degree of uniformity in judging the comparative merits of a considerable number of samples of unknown origin placed before them in January, 1910.

In 1908 selected strains of seed of one or both of these hybrids were distributed to several hundred Maryland tobacco growers with requests for a report as to merits compared with the type they were already growing. Considerable difference of opinion was expressed in these reports, as was to be expected, since most of the reports were not based on accurate experiments but were expressions of the ideas based upon general impressions gathered during the growth, curing, and handling of the crop. The majority of the reports, however, were favorable to the new seed, and, as a matter of fact, a considerable number of the best growers in southern Maryland are actually using one or the other of these hybrids, generally the Connecticut Broadleaf cross, for their entire commercial crop.

Several of the best growers report a materially increased yield and a higher average price per pound from the hybrid seed, as compared with the regular Maryland stock which they had formerly used.

Others, however, make the criticism that on rich land the hybrids grow so large as to make it difficult to handle the tobacco in harvesting without much damage from breaking. The increased liability to damage from house burn, particularly in the case of the Connecticut Broadleaf hybrid, was also a subject of criticism in a number of cases owing to the thick setting, size, and breadth of the leaves. Actually this last criticism seems to have the most substantial basis.

In connection with the straight selection work with the native Maryland types, there has been a development of considerable scientific interest which is well worth mentioning here.

In 1904 Messrs. Brown and Cobey saved seed under bag from a selected plant on the farm of Mr. James Gray in Charles County. In 1905, 100 plants were grown from this seed which were rather late in maturing, as the leaves were set thickly together on the stalk. Seed was saved under bag from the best looking plant of this generation. In 1906 100 plants were again grown from this second generation stock, and from among these developed three plants of strikingly modified characteristics. The leaves were remarkably thick-set on the stalk, and instead of developing the normal number of 20 or 25 leaves to the plant, as did the other plants of the row, these three went on multiplying the leaves at a rapid rate, showing, at the normal time of harvesting, no signs of throwing out a seed head. Two of these plants were transplanted to the greenhouse in October and the third was cut and the root stock was transplanted to the greenhouse. The two plants transplanted entire developed upwards of 100 leaves each and finally threw out seed heads in December from which seed was secured, while the root stocks threw out suckers which matured seed at about the same time.

From the seed of these three plants and their progeny test rows have been grown in each of the succeeding four years to date, and every plant in the stock has persistently adhered with striking uniformity to the types as set by the three original plants. They have averaged upwards of 100 average-sized leaves on a stalk about 8 feet tall at maturity, and none have showed any tendency to throw out a seed head during the normal growing season in the field. New seed has been obtained each year by transplanting a few root stocks to the greenhouse.

It has not been considered that this strain has possessed any great direct commercial value, but for cross-breeding upon other varieties its value may in the end prove to be very great.

The quality of the cured leaves from the few rows of this strain grown in 1908 and 1909 suggested the desirability, however, of making a real test of its commercial value. In 1910 therefore a half-acre field was planted with the strain. Every plant came true to type and was topped at from 40 to 50 leaves at the normal time for topping without any sign of a seed head appearing, so that the plants might prospectively ripen down and be ready for harvest at the normal curing season. Almost no suckers developed on the plants.

The commercial value of this test, however, was largely negatived by an unusually destructive hail storm in August. The test will be repeated in 1911. A number of crosses with this strain have already been made, the value of which is yet to be determined. All of the crosses, however, have blossomed at the normal time and have produced about the same number of leaves and quality of product as the normal strains or varieties with which the strain was crossed.

COMPARISON OF YIELDS OF FIRST-GENERATION TOBACCO HYBRIDS WITH THOSE OF PARENT PLANTS

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Wooster, Ohio

Some four years ago the writer first became convinced of the commercial possibilities of growing certain crops as first-generation hybrids. Steps were taken to put this idea to a practical test so far as it related to corn and tobacco. Circumstances did not permit starting the work with tobacco until 1907, when hybrids were made in such a way as to serve this purpose in addition to their usefulness as a means of obtaining new varieties by selection.

The corresponding experiment with corn was started immediately, in a small way, as a private enterprise. The corn results can here receive but the briefest mention. Suffice it to say that two distinct varieties of corn were bred up by the ear-row test and subsequent breeding plot in the manner followed by Professor Williams. Each year the remnants of the highest yielding ears of the two varieties were hybridized in addition to the cross-breeding of the same high

yielding ears with other ears of their own variety. In each of the four years' results these first-generation hybrids have outyielded both parent sorts, producing the highest yielding ears in the ear-row tests each time. The interesting point is that these highest yielding ears as sires and dams, whether bred together or crossed by their parent sorts, were inferior to the lower yielding ears of the pure varieties when crossed by each other.

In the winter of 1908 the writer, through a letter to Prof. A. D. Selby, then attending a smoking test of Ohio cigar filler tobaccos at Washington, D. C., called the attention of tobacco men to the possibilities of growing first-generation tobacco hybrids on a commercial scale. At that time some expressed their apprehension that the cost of producing the necessary seed would be a fatal drawback, but I am satisfied this is not a serious problem. The tobacco breeding work of the Ohio Agricultural Experiment Station was begun in the Miami Valley cigar filler district at Germantown, Ohio, in 1903, by making a number of hybrids of Cuban and Connecticut Seedleaf. The experiments which form the basis of this paper were all conducted with ciger filler types.

The first plants from hybrid seed were produced in 1904 and had the appearance of being more productive than the average of their parents, probably about equaling that of the higher yielding parent, Connecticut Seedleaf. That year additional crosses were made, most of them between these first-generation Cuban-Connecticut Seedleaf hybrids and either Zimmer-Spanish or Ohio Seedleaf; also one cross each of Zimmer by Ohio Seedleaf and Zimmer by Cuban.

The first generation of these new hybrids grown in 1905, for the most part, showed remarkable vigor of growth, but, as would be expected, since one parent itself was an unfixed hybrid, most of them were somewhat lacking in uniformity. However, their variability was very small compared with that exhibited by the second generation of their hybrid parent propagated by self-fertilized seed. The Zimmer-Cuban and Zimmer-Ohio Seedleaf hybrids were very unifrom and the latter exceedingly vigorous.

During these first two years' work the yields of the new hybrids were not determined separately, but their great vigor and productiveness were such as to suggest the desirability of obtaining such data in the future and also of determining the effect of cross-fertilization within the limits of a fixed variety.

CROSS BREEDING WITHIN THE LIMITS OF A SINGLE VARIETY

For the latter purpose Zimmer-Spanish was chosen as being the dominant variety of the region. Subsequent developments indicate that the choice of this variety was unfortunate in some respects and peculiarly fortunate in others. Zimmer-Spanish tobacco is beyond all doubt the most fixed and unvariable variety, not only of tobacco but of any species of plants with which I have worked; and, furthermore, I believe it to be identical with Connecticut Havana, largely raised in Connecticut for wrapper purposes. Indeed, plants grown from seed brought directly from Connecticut, for the purpose of determining the effect of change of climate on nicotine content, were absolutely indistinguishable at all stages, from the seed bed to the cured tobacco, from Zimmer-Spanish plants grown alongside. The same was true the following year with plants of the next generation. Every tobacco man asked to identify these Connecticut Havana plants immediately and unhesitatingly pronounced them Zimmer-Spanish. The results obtained from crossing within this variety are not in accord with those obtained by Shamel working with another variety, Connecticut Broadleaf, I believe.

In starting this experiment great care was taken to make uniform all factors affecting yield, except the matter of fertilization. Six plants were chosen and each plant allowed to produce twenty pods of seed, ten of which were self-fertilized and the remaining ten were cross-fertilized, pollinating an equal number with pollen derived from each of the other five plants. Thus there resulted 60 pods of selfed seed and 60 of crossed seed, and furthermore each of the six plants was equally represented in the production of both lots of seed. The plants grown from these two lots of seed were indistinguishable in the field, but the crossbred lot produced about 10 per cent greater yield. Four of the best plants were selected from each lot to continue the test the following year. This again resulted in a slight gain for the descendants of the crossed seed.

In 1907 this line of work was started anew in a slightly different manner. Pairs of plants were selected and one-half the flowers of each were crossed by the other member of the pair and the remainder allowed to self-pollinate. This gave rise to four lots of seed from each pair, two from each plant, one of which arose from self and the other from cross-fertilization. The four plantings for the next year's test consisted of each parent plant propagated through self-fertilized seed and the reciprocal crosses of the two parents.

Three pairs were used and the work done in duplicate, making a total of 24 plantings. The average increase of the reciprocal crosses over the average of their parents was, respectively, 22, 28, and 22 pounds per acre. Such small amounts are within the limit of error. It would seem that these results, taken together with the complete failure of our long-continued efforts to increase the yield of this variety permanently by selection, would indicate almost absolute invariability so far as concerns hereditary characters having to do with yield. Furthermore, the remarkable uniformity in the second and later generations would indicate lack of variability in *all* hereditary characters which have any external manifestations whatsoever.

The difficulties of controlling all the conditions affecting the yield of a transplanted crop are so great as to make it impossible to determine from the data at hand whether there are fluctuations temporarily inheritable or not. It is very desirable that similar studies be undertaken with other varieties which show greater tendency to vary. In this connection it may be well to state that quite a number of crosses have been made within the limits of more or less fixed hybrid varieties, always with an increase of yield in the first generation, which becomes greater as the relationship between the parent plants becomes more remote.

These results are not altogether in harmony with the contention that line breeding is superior to narrow breeding, at least not for the first generation.

CROSSES BETWEEN DISTINCT VARIETIES

Before going into the details of the experiments forming the basis of this discussion, I wish to state that the opportunity was not present to make this line of investigation a major one. Nearly all of these hybrids were made primarily for another purpose. The results in yield and apparent quality, however, have been such as to make me very enthusiastic as to the possibility of growing first-generation hybrid tobacco as the main crop, and it is hoped to make this subject one of the major considerations in our breeding work for the immediate future.

RESULTS IN 1908

The yields of first-generation hybrids and their parental varieties for this year are shown graphically on Chart 1. Pairs of plants were chosen and treated exactly as were the pairs of Zimmer-Spanish

already described. All plantings were made in duplicate. The shaded columns on either side represent the average yield of the two parents respectively, and the black column shows the average yield of their reciprocal crosses. Note that in all cases the hybrid exceeds, not only the average parental yield, but also that of the more productive parent. The minimum increase per acre is 67 pounds, or 7½ per cent, while the maximum is 285 pounds, or 31 per cent, the average being 165 pounds, or 17½ per cent.

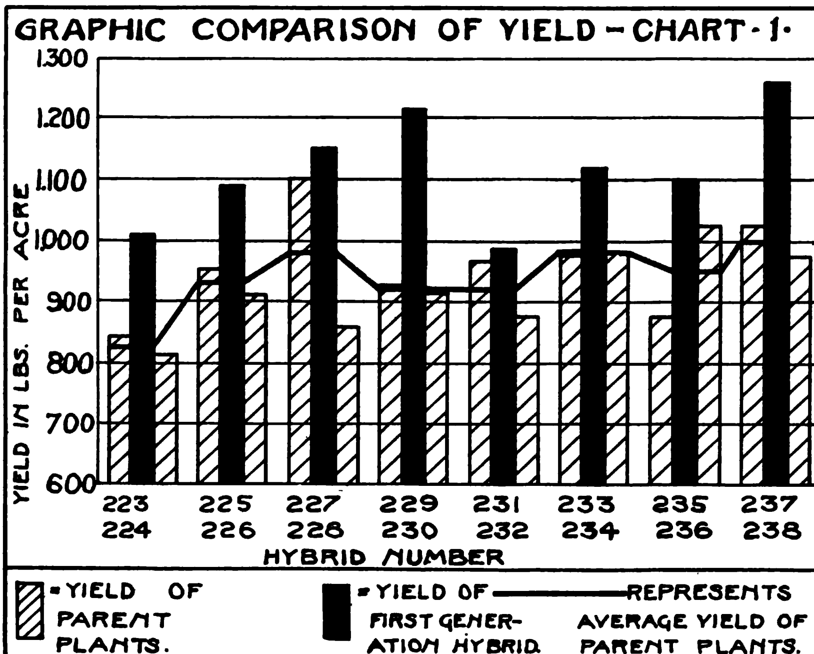

CHART 1. COMPARISON OF YIELDS OF FIRST GENERATION TOBACCO HYBRIDS WITH THOSE OF PARENT STOCK.

The results of reciprocal hybrids were so similar that, under pressure of lack of ground for testing, subsequent crosses were made in but one direction.

In a few instances one parent plant was not propagated, as inferiority became evident at stripping time. In these cases the parental yield was calculated by taking the average yield of sister plants. This is manifestly somewhat unfair to the hybrids, since good plants on the average possess greater hereditary yielding power than poor ones of the same parentage.

RESULTS IN 1909

Thirty-nine new hybrids were tested, the yields of which, together with those of their parent plants, are in part shown on Charts 2 and 3.

The parent plants of this group exhibit a much wider range of yield, both as to the two parents of a single hybrid and as to the group as a whole, than was found to exist among the parents of the 1908 group. An inspection of the charts will show that the hybrids have in most cases yielded considerably more than the parental average, but that in a considerable number of crosses the more productive parent has

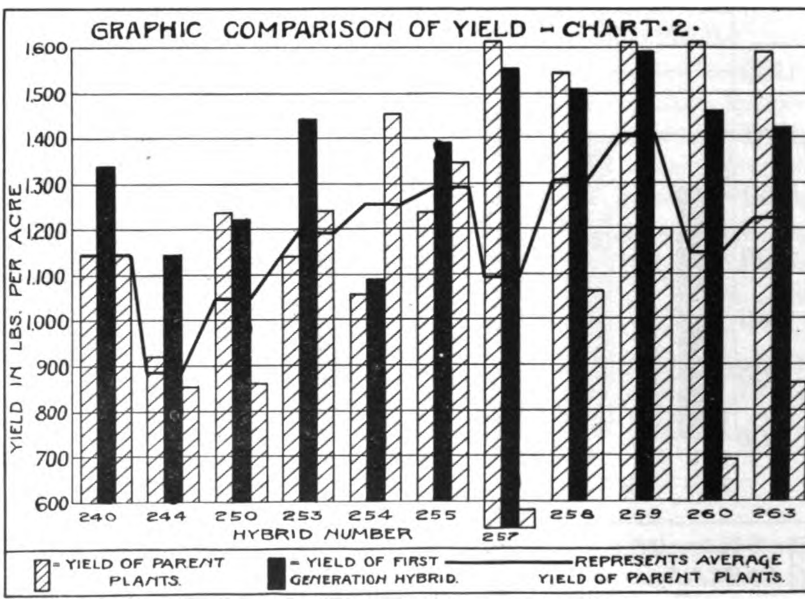

CHART 2. COMPARISON OF YIELDS OF FIRST GENERATION TOBACCO HYBRIDS WITH THOSE OF PARENT STOCK.

out-yielded the hybrid. In one instance the hybrid has fallen below the parental average, but this falls in the class already mentioned where one parent had been rejected because of evident inferiority at stripping time and the parental yield determined from the average yield of sister plants. Had the actual parent been used it is probable the results obtained would have been in harmony with the rest. It should be stated that the cases of rejection of a parent plant only occurred in instances where unfixed hybrids were used for crossing, as in such cases it is sometimes impossible to tell the better plants at blooming time.

The range of hybrid yields for 1909 as compared to that of their parents has for its minimum a decrease per acre of 160 pounds, or 13 per cent, while the maximum is an increase of 492 pounds, or 57 per cent. The average hybrid yield is 185 pounds, or 16 per cent greater, per acre than that of the parent plants.

DISCUSSION OF RESULTS

Before going further into this discussion, which is more or less speculative, it may be well to state that, notwithstanding our inability

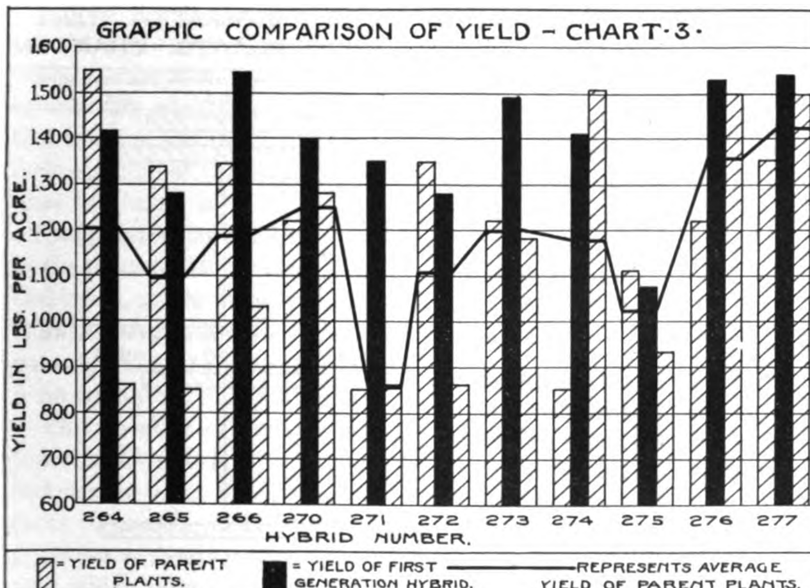

CHART 3. COMPARISON OF YIELDS OF FIRST GENERATION TOBACCO HYBRIDS WITH THOSE OF PARENT STOCK.

to single out the unit characters concerned; notwithstanding their apparent blending in the first generation and their subsequent apparent failure to segregate, it is the belief of the writer that Mendelian law offers the best explanation of the hereditary transmission of such qualities as productiveness. We furthermore invoke the "presence and absence of hypothesis" promulgated by Shull as the most reasonable explanation of the constitution of a Mendelian pair. It may be added that different degrees or intensities probably behave in the same manner as presence and absence.

The difficulties of reducing such qualities as yield to conformity

with Mendelian law probably arise from the exceedingly complex character of such attributes as compared with those which have been easily shown to behave in accordance with these laws. Since the number of unit characters concerned is probably very large, the number of possible combinations becomes almost infinite, each combination having its own visible expression, since we are not able to observe the unit characters singly, but only the resultant of their complex interrelations among themselves. Furthermore, we assume that yield characters may be either positive or negative. By a negative character we

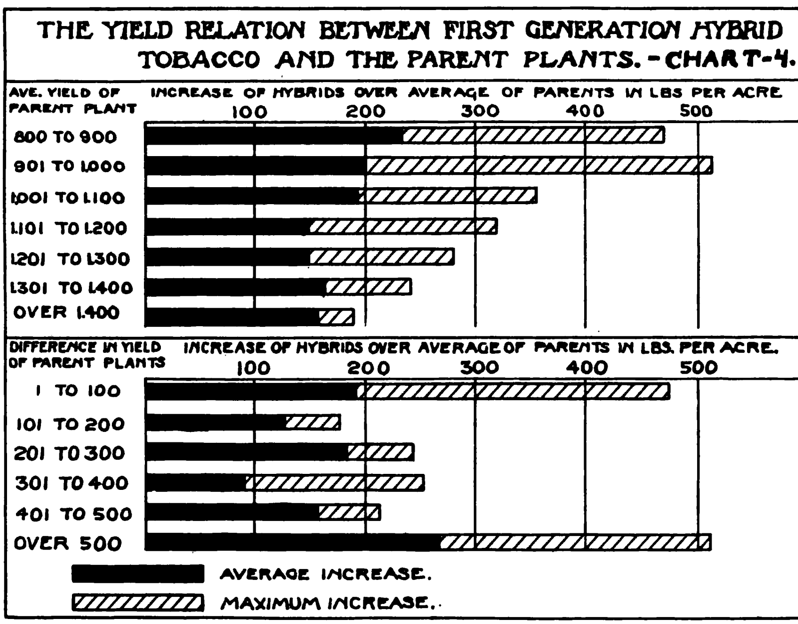

CHART 4. COMPARISON OF YIELD OF FIRST GENERATION TOBACCO HYBRIDS WITH THOSE OF THE PARENT STOCK.

[*Note of error.* In this figure the second column from the top in the upper section and the lower one in the lower section should reach only to 462 for the maximum increase instead of beyond 500 as in the figure. For correct fig. see Ohio Bulletin 239.]

mean one that produces a positive tendency in the plant to expend energy in unprofitable directions.

RELATION OF PARENTAL YIELD TO THAT OF HYBRIDS

The upper section of Chart 4 shows the hybrids grouped according to the average yield of their parents, giving both their average and maximum increase over their parents. The evidence is very strong

that as the average yield of the parents becomes greater the excess yield of the hybrid over the parental average grows smaller. This is more conspicuous in maximum than in the average increase.

In the lower section of the same chart the hybrids are grouped with respect to the difference in yield of their parents. The evidence here is not altogether clear, but it is my opinion that, other things being equal, large differences in the parental yields tend to augment the increase of the first-generation hybrid over the parental average. The irregularities probably arise from the fact that the inheritable factors that influence yield are many, both positive and negative.

If this be true, it is evident that when the more productive parent possesses all the positive yield factors found in the lower yielding one, with an exception to be noted later, there can be no advantage in hybridizing with the latter so far as yield is concerned. In a case like this the less productive parent may differ from the other (1) by lacking some of the positive yield factors; (2) by possessing negative ones not found in the other; and (3) by a combination of both. As already stated, by a negative yield factor is meant a positive tendency of the plant to devote energy to the production of parts of no commercial value, as, for instance, the suckering habit of tobacco. It follows that in cases 2 and 3 the hybrid can not reach the yield of the best parent, and that in case 1 it can not exceed it, that is, providing there is no advantage in heterozygosis *as such*.

This question of the ultimate nature of the increase of vigor to be found in first-generation hybrids can not here be discussed at length, but it may be said that it does not seem to be in conflict with known facts to assume that, under some circumstances at least, heterozygosis *per se is* advantageous. Leaving for a moment the hidden factors which influence yield and turning to the visible unit characters which have been studied, we see that environment influences development. Indeed some characters may be entirely suppressed even in homozygotes, and much more frequently in heterozygotes.

Now turning again to yield characters, may it not be possible that heterozygosis in some measure makes the organism independent of its environment, giving it as it were a power of choice, allowing it to develop along the lines of least resistance, concentrating its energy in those directions most favored by the environment. While the homozygote, less responsive to environment, expends more energy in unprofitable directions. This interpretation is in entire harmony with the fact recently pointed out by Collins that first-generation corn hybrids have a much wider range of adaptability than fixed varieties. This

view does not preclude the possible fact that plants homozygous in all the factors which increase yield would not equal or even surpass heterozygotes when the environment was favorable to the development of all, or nearly all, the characters concerned.

When looked at from the Mendelian viewpoint it becomes quite evident that either negative yield characters sometimes play a very important rôle or else that the homozygous state of the characters found in a heterozygous condition in the first generation is a decided advantage under certain conditions, for sometimes in the third and later generations yields appear much in excess even of the first generation. Notwithstanding the great gains shown by first-generation hybrids over their parents, we have never yet produced a first-generation yield equal to the combined yield of both parents, a feat which has been accomplished several times in later generations. I think the elimination of negative characters is the principal cause of this increased productiveness.

It is an interesting fact that even after we have by selection pushed the yield beyond that of the first generation we can still further augment it by crossing these high yielding strains by other similarly obtained even if they have been derived from the same original hybridization. The first generation of these intercrosses again yields above the parents.

It will be interesting to see how far we can push this "see-saw" game of elevating yields by alternating hybridization with selection. As we advance the difficulties multiply. In the first place, as the absolute yield of the first generation increases it becomes more and more difficult to surpass it in later ones. This could arise either from the fact that the negative factors are almost completely eliminated, in which case, barring the possibility of favorable mutation, or possible advantage of homozygosis *as such*, we are approaching the upper limit of production possible without the introduction of new blood.

The same difficulty could arise if the number of positive inheritable units found in one or the other of the parents but not in both is so large that it becomes practically impossible to combine them all in the homozygous state in a single individual. The numerical average ratio of such an individual to the total number of plants of the second generation will be as 1 is to that power of 4 represented by the number of Mendelian units concerned. Thus if but two factors are involved, one in every 16 plants will have the sought-after combination, but if 10 factors are involved, then only one plant in 1,048,576 will meet

the required conditions. Even if it were possible to grow a million plants, it would *not* be possible to pick out the one plant containing all the characters in homozygous state, because hereditary yielding power can only be surely discovered by trial, and differences of environment would form another disturbing element of great importance. If we assume 20 unit characters instead of 10—a by no means impossible number—it would require more than a trillion plants to give an even chance of producing all the possible combinations.

I am convinced that it is here, at least in part, that we must look for a solution of the problem presented by the great difficulty of producing fixed varieties of tobaccos which can not be surpassed in yield by the first-generation hybrids of themselves crossed by other varieties of equal worth. It would seem that the evidence already at hand would indicate that as the foundation stock used for hybridizing becomes more highly developed, we may expect the best fixed strains of hybrids which can be developed by practical means to gradually lose in relative yield until they fall below the yield of the first-generation hybrid and finally below that of their parents. Should this prove to be the case then first-generation hybrids offer the one chance of getting the highest possible yields.

COMMERCIAL OUTLOOK

We shall now turn to the commercial aspects of the matter. The questions most likely to arise in the grower's mind are, What will it cost to produce hybrid seed? Will the tobacco be uniform? Will the quality be equal to that of existing varieties?

In answer to the first question I think the difficulties of perpetuating first-generation tobacco hybrids can surely be no greater than those connected with the vegetative multiplication of fruit trees which are first generation hybrids. Indeed, I believe the cost is much less than with trees which necessitate grafting. The number of seeds produced from a single flower are so enormous and the work of hybridizing so easy that the extra expense is insignificant in comparison with the increased yield which may be obtained. From my personal experience I think it can be conservatively stated that the added cost should not exceed 25 cents per acre when the hybrid seed is produced on a moderately large scale, and not over 50 cents when the amount produced is very small.

It would not be necessary to produce seed anew each year, as tobacco seed retains its viability for a long time. Many farmers

growing tobacco in the ordinary manner do not save seed oftener than once in three years.

In answer to the second question it may be said that first-generation hybrids will not show essential difference in uniformity from the parent varieties. Indeed, if one or both parents are unfixed hybrids the first generation will be somewhat more uniform than the parents. Such parents, however, should be avoided and only fixed hybrids or straight varieties used when the end sought is the commercial usefulness of the first-generation hybrid.

The matter of quality is not quite so easy of solution, but offers no difficulty not present in a new variety derived by other means. In general, it may be said that the various factors which go to make up quality will be more or less intermediate between those of the parents. This to a certain extent furnishes a guide in selecting foundation stock, but, as in the matter of yield, the best combination can be finally determined only by trial. So far as quality is correlated with vigor of growth, the hybrid is likely to excel the parents. In certain cases this is a factor not to be neglected. It should be remembered that anything which increases yield, whether it be fertilization, cultivation, or inherent vigor, tends at the same time to enhance quality.

The Station has several hybrids the first generations of which seem to possess a very desirable combination of quality and yield, but further testing will be done before offering them for distribution.

COMPARATIVE YIELDS AS RELATED TO SOIL FERTILITY

The inheritable characters which make for yield are of two kinds—those that confer power to abstract food from the soil, and those that increase the capacity to use such food. The latter may be subdivided into those giving absolute capacity to given parts or to the organism as a whole, and into those which govern the distribution of growth among the various parts. To illustrate: When the capacity for obtaining food is already the limiting factor of growth it is obvious that no amount of augmentation of consumptive capacity will increase the yield. We have tested hybrids that under conditions producing 800 pounds of Spanish per acre have yielded but 700 pounds; when the yield of Spanish rose to 1000 pounds it was equaled by that of the hybrid; but when the Spanish yield reached 1200 the hybrid produced over 1500 pounds.

The interesting point in this connection for the breeder is that it seems much easier in the case of the tobacco plant to increase the

capacity to use food than it is to increase the capacity to obtain it. Should it be found that this same relation to soil fertility holds good with other plants it may have an important bearing on the solution of the ever-increasing problem of our food supply. May we not wisely conduct a part of our breeding experiments with this end in view. Why not supply plant food to an extent that would be wasteful with our present varieties and then breed up until we obtain varieties that can make economical use of this excess of food. For after all, other things being equal, is not that plant best which can make use of the greatest amount of food? With but few exceptions, from the standpoint of usefulness to man, the best animals are the ones having the power to convert with the least waste the greatest amount of food into more valuable products. By the same token may we know the best plants.

WORK WITH SEEDLING SUGAR CANES IN THE BRITISH WEST INDIES AND BRITISH GUIANA

FRANCIS WATTS

Barbados, West Indies

Since the establishment of the fact, in 1887 and 1888, by Professor Soltwedel, in Java, and Prof. J. B. Harrison, C.M.G., and Mr. J. R. Bovell, I.S.O., in Barbados, that the sugar cane is capable of bearing fertile seeds, systematic work has been carried on in the West Indies and British Guiana for the purpose of obtaining improved varieties of seedling canes.

In the years 1901–1906, more than 20,000 seedling canes were raised and planted out in Barbados; but less than 1 per cent of those was permitted to pass the tests of field and chemical selection that were applied to them. Further, over 7000 plants were raised from seed in 1904-5, and of these only 95 were reserved for further propagation. Taking a longer period, it is worthy of note that during the eleven years ending in 1909, nearly 37,100 varieties of sugar cane have been raised from seed, and all these have been examined for the purpose of selection and the subsequent propagation of varieties that seem worthy of this. At the present time, three kinds of seedling canes are raised in Barbados: (1) Artificial hybrids, which are obtained after emasculating flowers of the best variety before the anthers open

bagging them to prevent pollination by unknown kinds, and pollinating them with pollen that has been taken from some of the best varieties; (2) natural hybrids, for the obtaining of which different varieties of sugar cane are planted chess board fashion, in order to give the best chance for cross-pollination; (3) self-fertilized seedlings, which are obtained by bagging the arrows of some of the best varieties before pollen is escaping from the anthers, thus insuring that cross-fertilization does not take place.

The extent of the work that is being carried on in British Guiana may be gauged from the fact that in the season 1908–9, sugar cane seeds were sown in 461 boxes, and 20,260 seeds germinated. In the end, 13,050 plants from the seeds were transferred to baskets and 4600 were selected for cultivation and observation.

Similar work has also been carried out in Trinidad and Jamaica, but on a much smaller scale, and also to a small extent in Antigua.

The names of the chief workers in British Guiana and the West Indies, in connection with the production of seedling canes, are as follows:

British Guiana: Prof. J. B. Harrison, C.M.G., Director of Science and Agriculture, and F. A. Stockdale, B.A. Cantab., Assistant Director of Science and Agriculture.

Barbados: J. R. Bovell, I.S.O., Superintendent of Agriculture.

Trinidad: Prof. P. Carmody, F.I.C., F.C.S., Director of Agriculture.

Jamaica: The Hon. H. H. Cousin, M.A., Director of Agriculture.

Assistance has also been given in the matter, in the past, in Barbados, by Mr. L. Lewton-Brain, B.A., Cantab., Director of Agriculture for the Straits and Federated Malay States, and by Mr. F. A. Stockdale, B. A., Cantab., now Assistant Director of Science and Agriculture, British Guiana, while they were officers on the Staff of the Imperial Department of Agriculture for the West Indies.

The following references may be made in connection with the literature on the subject:

West Indian Bulletin, vol. vii, p. 364.

Progress Report on the Experimental Agricultural Work of the Department of Science and Agriculture, British Guiana, April 1, 1908, to September 30, 1909.

Barbados: Report of the Agricultural Work for 1907–9. Carried on under the Direction of the Imperial Department of Agriculture for the West Indies.

Seedling Canes and Manurial Experiments at Barbados 1908-10 (Pamphlet No. 66 of the series issued by the Imperial Department of Agriculture for the West Indies).

LIST OF PUBLICATIONS ON BREEDING SUGAR PLANTS IN THE REPORTS OF THE AMERICAN BREEDERS ASSOCIATION

Submitted by W. A. ORTON, *Chairman*

SUGAR CANE:

Improvement of Sugar Cane by Selection and Hybridization. By F. A. Stockdale, B.A., Imperial Department of Agriculture for the West Indies. A. B. A. II, p. 148.

The Improvement of Sugar Cane by Selection and Breeding. By C. O. Townsend, U. S. Department of Agriculture. A. B. A. III, p. 105.

Seedling Sugar Canes in Louisiana. By W. R. Dodson. A. B. A. V, p. 274.

SUGAR BEETS:

Breeding Sugar Beets for Increase of Sugar Content and Yield. By J. E. W. Tracy, U. S. Department of Agriculture. A. B. A. III, p. 102.

Work Conducted by the U. S. Department of Agriculture in Breeding High Grade Strains of Sugar Beet Seed and Testing Important Varieties. By J. E. W. Tracy, U. S. Department of Agriculture. A. B. A. V, p. 284.

SORGHUM BREEDING:

Breeding Sorghum. By C. O. Townsend, U. S. Department of Agriculture. A. B. A. V, p. 269.

SUGAR CROPS:

Report of Committee on Breeding Sugar Crops. A. B. A. III, p. 101.

A MENDELIAN STUDY OF TOMATOES

A. W. GILBERT

Ithaca, New York

Tomatoes present a fertile field for the student of evolution. Their introduction as cultivated plants has been quite recent and their subsequent improvement has been rapid. In the work of Bailey,[a] Price and Drinkard,[b] Hedrick,[c] White,[d] Craig,[e] and others our knowledge of tomato breeding becomes centered.

Tomatoes are well adapted to Mendelian study. The crossing of them is easy and their subsequent cultivation presents no great difficulty. They contain, also, many distinct heritable units. The principal drawback to their use for this purpose is that they are not normally self-fertilized, and the amount of bagging necessary to prevent promiscuous crossing is tedious and time-consuming.

These experiments were begun in the summer of 1908, commercial varieties being used for parents. A continuous self-fertilization of

[a] Bailey, L. H. Survival of the Unlike.
[b] Price, H. L., and Drinkard, A. W. Inheritance in Tomato Hybrids. Va. Bul. 177, 1908.
[c] Hedrick, U. P. Society for Horticultural Science, Proceedings, 1907.
[d] White, C. A. Science, XIV, 1901, and XVII, 1903.
[e] Craig, A. G. Society for Horticultural Science, Proceedings, 1907.

these varieties for three years has shown that they were remarkably pure and true to type.

In order to obtain a fuller understanding of the results obtained from these experiments, a brief history of tomatoes is here given. The tomato has undergone a remarkable transformation.

Cherry tomato	Pear-shaped sorts—Oblong sorts.	
	Orangefield, etc.—Angular sorts.	
	Green Gage, Large Yellow, White Apple, etc.—large yellow sorts.	
	Little Gem, the Cook's Favorite, etc.—large red sorts.	Grandifolium. Validum.

Here we see that, according to Bailey, the cherry tomato, with its small red fruits, is the progenitor of the varieties of tomatoes now extensively grown. This evolution has taken place in a relatively short time by means of mutation and hybridization. Most of the mutations which doubtless have taken place have never been recorded, but the history of a few of them is definitely known. In regard to the origin of the upright type which has a very characteristic large stem and crinkly leaf, of which the variety Quarter Century is a good sample, Bailey says (*Survival of the Unlike*, p. 116): "This curious race came in suddenly, without any premonition, so far as we know, of its appearing, and the same thing has probably not appeared a second time." Similarly Bailey describes (*Plant-Breeding*, p. 123) the origin of the Ignotum tomato as a mutation. The Trophy tomato, which holds such a prominent place in the history of the cultivated tomato, was produced by crossing together "the small smooth 'Love Apple,' which was filled with juice and seeds, with the compound, convoluted tomato of that period" (1850). After this cross was made, selection was carried on for many generations before the variety reached its perfection.

The cultivated varieties of tomatoes are very subject to deterioration and reversion. Constant selection is necessary to keep up the type. Much of this is due probably to the cross-fertilization and vicinism to which tomatoes are very subject.

White records (*Science*, xiv, 841–844, 1901, and xvii, 76–79, 1903) three very interesting instances of the complete change of one type of tomato into another resulting from change of conditions. In the first case (see ref. 1901) he planted in his garden the seed of the Acme tomato and the resulting crop came true to seed the first year. The seeds from these fruits were saved and planted the next year. The fruit which resulted this second year all showed a diversion from the

original Acme into an entirely new and distinct type. This new form, which was named the "Washington" tomato, seems to be a progressive mutation. It is very similar to such sorts as the Quarter Century and Dwarf Champion, which are the newest forms which the tomato has given us. This complete change was presumably due to the very different environment under which the plants of the previous year were grown as compared with former years.

The other two cases which White records are equally striking. It was shown that where our common large red tomatoes, Trophy in one case, are grown in Louisiana or Cuba for one year, the resulting seed, when grown, gives plants all of which revert back to the Cherry tomato, the progenitor of the race. This last phenomenon has been observed to occur several times. It cannot be due to hybridization, because the plants were isolated and the progeny were entirely uniform in the second generation, which would not have been the case if crossing had taken place.

If these are cases of mutation, as they possibly may be, they are certainly very unusual cases.

Bailey gives (*Survival of the Unlike*) the following classification of cultivated tomatoes, which will be of service here to give a better understanding of the forms used in these experiments:

LYCOPERSICUM ESCULENTUM, Miller, Gard. Dict. (1768)

§A. *Cerasiforme.*—Cherry tomatoes (*L. cerasiforme*, Dunal, Hist. Solan. 113). Fruit spherical, two-celled, the original type.

§B. *Pyriforme.*—Pear and Plum tomatoes (*L. pyriforme*, Dunal, l. c. 112). Fruit oblong or pyriform, two-celled, conspicuously pendent.

§§A. *Vulgare.*—Plant weak, requiring support; leaves ordinary.

Group 1. Angular tomatoes. Fruit medium or below in size, mostly, very flat, plane on top, more or less angular, the lobes most conspicuous on the bottom and sides. Developed directly from the Cherry tomato, through the type of Improved Large Yellow, etc. Tom Thumb may be taken as the type of the group.

Group 2. Apple-shaped tomatoes. Fruit normally more or less rounded on top, most of the irregularities being due to the interposition of adventitious cells in the center of the fruit. Direct developments from the Cherry tomato, through its rounder and more regular forms. The "ringed" or "lined" character of the apex of the fruit is most often seen in this group. The Paragon may be taken as a type of the group.

Group 3. Oblong tomatoes. Fruit usually as long or longer than broad, the sides very firm. Developments from the pear-shaped variation. Criterion, in its normal forms, may be considered the type.

§§B. *Grandifolium.*—Habit the same as in subsection A; leaves very large; leaflets fewer (about two pairs), large (the blade three to four inches long and an inch and a half wide), entire, the lower side strongly decurrent on the petiolule. Leaves of very young plants are entire: Singular plants of recent development, represented by but few varieties, of which Mikado may be taken as the type.

§§C. *Validum.*—Stem very thick and stout, the plants nearly sustaining themselves, two to three feet high; leaves very dark green, short and dense, the leaflets wrinkled and more or less recurved. Odd plants, with the aspect of potatoes, represented by French Upright and the New Station.

The following crosses were made in 1907 and 1908 to test the behavior of unit characters in tomato hybrids. These are presented in tabular form to facilitate comparison. The varieties which were used for crossing are listed in the first column and the first and second-generation hybrids briefly described. More detailed accounts are presented in subsequent pages.

EXPERIMENTS.

Table of crosses and their allelomorphic pairs.

Variety crosses.	♀ characters.	♂ characters.	F_1 hybrids.	F_2 hybrids.	Field count Number of plants F_2 hybrids.
Pedigree No. 1: Red Pear × Yellow Pear	Red	Yellow	Red	Red Pear	163
				Yellow Pear	64
Pedigree No. 2: Red Pear × Ponderosa	Red, Pear shaped	Scarlet, large round	Red, intermediate	Pear	5
				Intermediate	26
				Ponderosa	2
Pedigree No. 3: Red Pear × Stone	Pear-shaped	Large round	Intermediate	Red Pear	20
				Red intermediate	75
				Red Stone	32
Pedigree No. 4: Red Pear × Yellow Plum	Red, Pear-shaped	Yellow, plum-shaped	Red, Plum	Red Pear	74
				Red Plum	114
				Yellow Pear	20
				Yellow Plum	42
Pedigree No. 5: Red Pear × Cherry	Pear-shaped.	Cherry-shaped	Cherry	Red Pear	15
				Red Cherry	45

Table of crosses and their allelomorphic pairs—Continued.

Variety Crosses.	♀ characters.	♂ characters.	F_1 hybrids.	F_2 hybrids.	Field count Number of plants F_2 hybrids.
Pedigree No. 6: Red Pear × Perfection	Pear-shaped.	Large round	Intermediate	Red Pear	29
				Red intermediate.	63
				Red Perfection	24
Pedigree No. 7: Red Pear × Trucker's Favorite	Pear-shaped	Large round	Intermediate	Red Pear	24
				Red intermediate.	82
				Red Trucker's Favorite	23
Pedigree No. 8: Yellow Pear × Earliana	Yellow, Pear-shaped	Red, large round	Red, Intermediate	Red Pear	24
				Red intermediate	64
				Red Earliana	35
				YellowPear	4
				Yellow intermediate	10
				Yellow Earliana	3
Pedigree No. 11: Red Pear × Earliana	Pear-shaped	Large round	Intermediate	Red Pear	34
				Red intermediate	75
				Red Earliana	26
Pedigree No. 12: Yellow Plum × Perfection	Yellow, plum-shaped	Red, large round	Red, intermediate	Red Plum	3
				Red intermediate	9
				Red Perfection	5
				Yellow Plum	1
				Yellow intermediate	4
				Yellow Perfection.	0
Pedigree No. 16: Yellow Pear × Trucker's Favorite	Yellow, pear-shaped	Red, large round	Red, intermediate	Red Pear	11
				Red intermediate	57
				Red Trucker's Favorite	12
				Yellow Pear	7
				Yellow intermediate	12
				Yellow Trucker's Favorite	7

Table of crosses and their allelomorphic pairs—Continued.

Variety.	♀ characters.	♂ characters.	F_1 hybrids.	F_2 hybrids.	Field count Number of plants F_2 hybrids.
Pedigree No. 18: Yellow Plum × Stone	Yellow, plum-shaped	Red, large round	Red, intermediate	Red Plum	23
				Red intermediate	58
				Red Stone	23
				Yellow Plum	14
				Yellow intermediate	24
				Yellow Stone	10
Pedigree No. 19: Yellow Plum × Yellow Pear	Plum-shaped	Pear-shaped	Plum	Plum	92
				Pear	84
Pedigree No. 20: Yellow Plum × Ponderosa	Yellow, plum-shaped	Scarlet, large round	Intermediate	Scarlet Plum	19
				Scarlet intermediate	56
				Scarlet Ponderosa	30
				Yellow Plum	7
				Yellow intermediate.	17
				Yellow Ponderosa	13
Pedigree No. 21: Yellow Plum × Earliana	Yellow, plum-shaped	Red, large round	Red, intermediate	Red Plum	11
				Red intermediate	24
				Red Earliana	3
				Yellow Plum	1
				Yellow intermediate	9
				Yellow Earliana	2

Table of crosses and their allelomorphic pairs—Continued.

Variety.	♀ characters.	♂ characters.	F_1 hybrids.	F_2 hybrids.	Field count Number of plants F_2 hybrids.
Pedigree No. 25: Yellow Plum × Quarter Century....	Standard plant, yellow, plum-shaped....	Dwarf plant red, large round....	Standard vine, red, intermediate	Red Plum dwarf..	1
				Red interm. dwarf	9
				Red Quarter Cent. dwarf...........	17
				Red Plum tall....	28
				Red interm. tall...	89
				Red. Qr. Cent. tall	19
				Yellow Plum dwarf	1
				Yellow interm. dwarf	3
				Yellow Qr. Cent. dwarf..........	6
				Yellow Plum tall..	4
				Yellow interm. tall.............	24
				Yellow Qr. Cent. tall..........	7
Pedigree No. 26: Red Cherry × Ponderosa.........	Red, small round.....	Scarlet, large round.....	Red, intermediate...	Red Cherry.......	8
				Red intermediate.	28
				Red Ponderosa....	7
				Scarlet Cherry....	5
				Scarlet intermediate............	8
				Scarlet Ponderosa.	6
Pedigree No. 28: Ponderosa × Quarter Century...	Scarlet, standard plant......	Red, dwarf plant......	Red, standard vine..	Red tall...........	58
				Scarlet tall........	26
				Red dwarf........	20
				Scarlet dwarf......	9
Pedigree No. 29: Stone × Yellow Pear	Red, large round.....	Yellow, Pear-shaped....	Red, intermediate...	Red Pear..........	18
				Red intermediate	68
				Red Stone.........	26
				Yellow Pear.......	9
				Yellow intermediate.........	23
				Yellow Stone......	6

RESULTS OF CROSSING.

The following data are grouped with respect to similar allelomorphs regardless of variety. The color or height of vine, for example, is not taken into account, but merely size and shape in the following table. The subsequent tables are arranged in the same manner.

SERIES 1.—*Pyriform* × *Large Round Fruit.*

Variety crosses.	♀	♂	F_1 Hybrids.	F_2 Hybrids.	Field Count No. of Plants.	Theoretical Count.
Pedigree No. 2: Red Pear × Ponderosa	Pear	Large round	Intermediate	Pear	5	8.2
				Intermediate	26	16.5
				Ponderosa	2	8.2
Pedigree No. 3: Red Pear × Stone	Pear	Large round	Intermediate	Pear	20	31.7
				Intermediate	75	63.5
				Stone	32	31.7
Pedigree No. 6: Red Pear × Perfection	Pear	Large round	Intermediate	Pear	29	29.0
				Intermediate	63	58.0
				Perfection	24	29.0
Pedigree No. 7: Red Pear × Trucker's Favorite	Pear	Large round	Intermediate	Pear	24	32.2
				Intermediate	82	64.5
				Trucker's Favorite	23	32.2
Pedigree No. 8: Yellow Pear × Earliana	Pear	Large round	Intermediate	Pear	28	35.0
				Intermediate	74	70.0
				Earliana	38	35.0
Pedigree No. 11: Red Pear × Earlana	Pear	Large round	Intermediate	Pear	34	33.7
				Intermediate	75	67.5
				Earliana	26	33.7
Pedigree No. 16: Yellow Pear × Trucker's Favorite	Pear	Large round	Intermediate	Pear	18	26.5
				Intermediate	69	53.0
				Trucker's Favorite	19	26.5
Pedigree No. 29: Stone × Yellow Pear	Large, round	Pear	Intermediate	Pear	27	37.5
				Intermediate	91	75.0
				Stone	32	37.5

SUMMARY OF SERIES 1.

Allelomorphs.	Observed Number.	Theoretical Number.
Pear-shaped	185	234
Intermediate	555	468
Large Round	196	234
Total	963	...

SERIES 2.—*Pyriform* × *Cherry.*

Variety cross.	♀	♂	F_1 hybrids.	F_2 hybrids.	Field count.	Theoretical count.
Pedigree No. 5: Red Pear × Red Cherry	Pear	Cherry	Cherry	Pear	15	15
				Cherry	45	45
				Total	60	..

Characteristics of parents.—The pear-shaped parent of these crosses is classified as *L. pyriforme*. The fruit has a very distinct neck and is pendent when growing. This type of tomatoes stands second in order of origin to the Cherry type. It is thus an older form than the large round sorts.

There is correlated with the pear-shaped tomatoes a type of corolla which is characteristic. It is much larger and more slender than the corolla of the large round varieties. In the pear tomatoes the corolla often persists until torn asunder by the lateral pressure of the developing fruit; and thus it often very materially modifies the form of the neck.

The round-fruited varieties, on the other hand, invariably possess a short corolla tube and one that is always larger than that of the pear varieties. In the crosses of this series we are dealing then with neck versus absence of neck; and small size versus large size, with which is correlated a long, slender corolla and a short, heavy corolla respectively.

The large red tomatoes used in these crosses varied somewhat in shape and size, but, in general, they were more or less apple-shaped, many fruits being irregular in outline and greatly ridged and grooved.

Results of crossing.—The tomatoes which resulted from crosses of this series were, as a rule, intermediate between the parents in size and shape and contained no neck in the F_1 generation. The form of corolla was somewhat similar to that correlated with the pear-shaped parent.

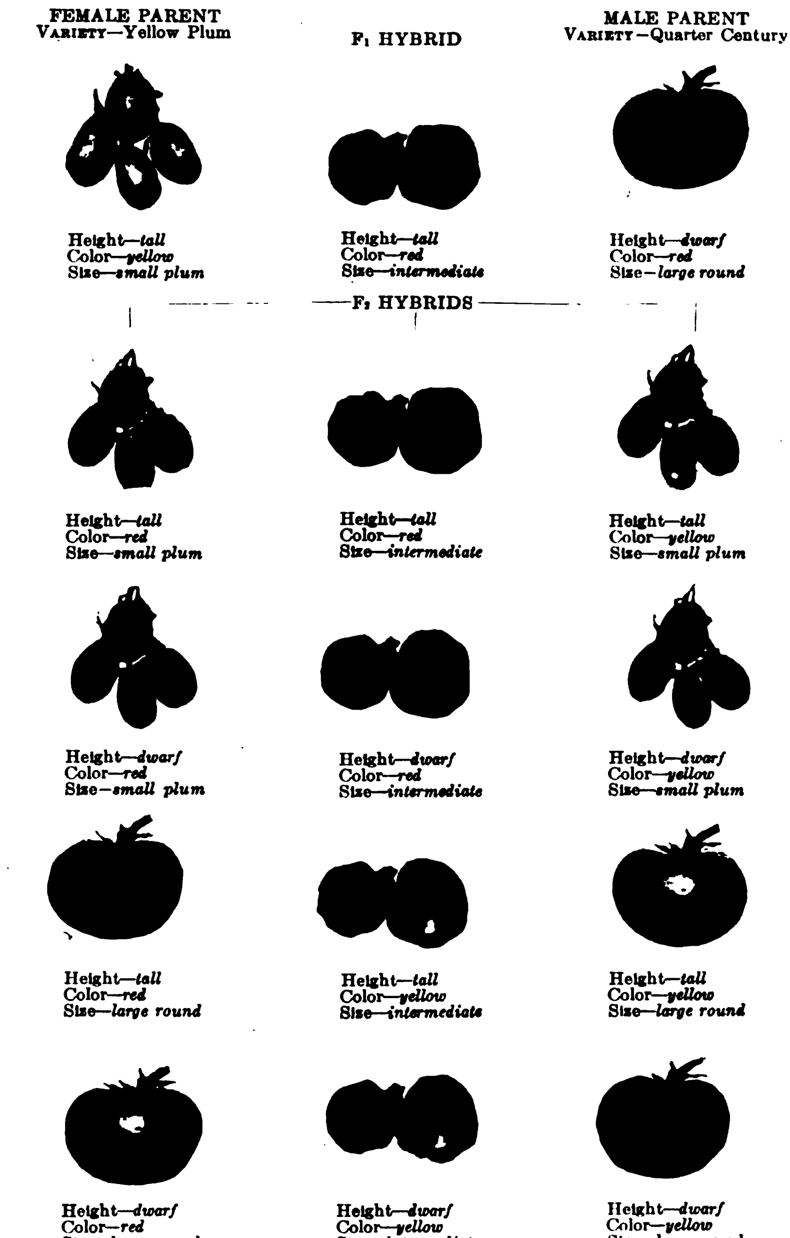

FIG. 1. GRAPHIC ILLUSTRATION OF SERIES 12 (YELLOW PLUM ♀ X QUARTER CENTURY ♂).
There were found in the field the 12 distinct types of F_2 hybrids as illustrated above. This redistribution of characters illustrated here represents a very important economic bearing of Mendel's law.

In the F_2 generation, three types were produced, namely, small pear-shaped, large round, and forms intermediate between the two; in fact, the kinds in the second generation range in an almost continuous series from one parent to the other. The indications are that there are many unit characters involved in the production of size and shape.

When taking data in the field it was impossible to tell in which class many plants belonged. There was an obvious tendency for the observer to record doubtful plants as belonging to the intermediate class, hence, this class has greater numbers than it should theoretically contain. Certain plants were apparently homozygous pear-shaped and homozygous large round, but many others were very questionable. It will require further study to determine if there are other unit characters involved than the ones of mere size and shape, which were used as a basis of this series.

SERIES 3.—*Pyriform × plum-shaped.*

Variety crosses.	♀	♂	F_1 hybrids.	F_2 hybrids.	Field count.	Theoretical count.
Pedigree No. 4: Red Pear × Yellow Plum	Pear, neck...	Plum, no neck....	No neck.....	Pear...............	94	62.4
				Plum...............	156	187.2
Pedigree No. 19: Yellow Plum × Yellow Pear........	Plum, no neck ..	Pear, neck ..	No neck.....	Plum..............	92	132.0
				Pear...............	84	44.0

SUMMARY OF SERIES 3.

Allelomorphs.	Observed Number.	Theoretical Number.
Pear...	178	106.4
Plum...	248	319.2
Total..	426	.....

Characteristics of parents.—The female parent of these crosses, Red Pear, is similar to that of Series 1, which has already been described. The male parent, which is of the Cherry type, is that type which is presumably the progenitor of the race. The fruits are small and round and grow in clusters, with a relatively large number of fruits in each cluster. There is associated with this fruit the same type of corolla

as is found in the pear and plum varieties, and small fruits are much earlier to mature than the large round types.

Results of crossing.—The fruits which result from this cross show almost complete dominance of the Cherry type of tomato over the pear-shaped type in the F_1 generation.

In the F_2 generation a complete segregation takes place into Cherry and Pear. A ratio of exactly 3:1 was observed in this series.

SERIES 4.—*Cherry × large round fruit.*

Variety cross.	♀	♂	F_1 hybrids.	F_2 hybrids.	Field count.	Theoretical count.
Pedigree No. 26 Red Cherry × Ponderosa..........	Cherry..	Large round	Intermediate	Cherry............	13	15.5
				Intermediate......	36	31.0
				Ponderosa	13	15.5
				Total..	62	....

Characteristics of parents.—The female parent is similar to that of Series 1 and 2, which have already been described. The male parent (plum-shaped) is somewhat similar to the pear-shaped except that it is longer, more oblong, and does not have the conspicuous neck which is to be observed in the pear-shaped types. This plum-shaped type of tomato has a corolla similar to the pear-shaped type and also the Cherry tomato.

Results of crossing.—The first-generation hybrids which result from these crosses are slightly variable, but show a strong tendency toward the plum-shaped and no tendency whatever toward the pear-shaped; the absence of neck is dominant over the presence of neck.

Among the F_2 hybrids, many types occur which are not distinctly pear or plum-shaped, hence in taking field data it was difficult to determine where to classify certain plants.

Characteristics of parents.—The large round fruit, Ponderosa, which was used as a female parent is of the type now most generally used for commercial purposes. This type of fruit is the newest in line of evolution of tomatoes. It has gradually been produced by means of mutation from the small Cherry, which was used in this series as the male parent. These large red fruits were quite variable, especially in the arrangement and shape of the grooves and ribs which form upon the surface of the fruit. Some fruits are very irregular, while others have a smooth and even surface. These fruits have a short stout

corolla, such as has already been described. These larger fruits are much later in season than such types as the Cherry, Pear, etc.

Results of crossing.—The F_1 hybrids are intermediate in size between the parents, and the number of fruits in a cluster is also intermediate. This is similar to Series 1. Three types occur in the second generation, as indicated in the table.

SERIES 5.—*Small plum-shaped fruit × large round fruit.*

Variety crosses.	♀	♂	F_2 hybrids.	Field count.	Theoretical count.
Pedigree No. 12: Yellow Plum × Perfection	Plum	Large round	Plum	4	5.4
			Intermediate	13	10.9
			Perfection	5	5.4
Pedigree No. 18: Yellow Plum × Stone	Plum	Large round	Plum	37	38.0
			Intermediate	82	68.5
			Stone	33	38.0
Pedigree No. 20: Yellow Plum × Ponderosa	Plum	Large round	Plum	26	35.4
			Intermediate	73	70.9
			Ponderosa	43	35.4
Pedigree No. 21: Yellow Plum × Earliana	Plum	Large round	Plum	20	12.4
			Intermediate	33	25.9
			Earliana	5	12.4
Pedigree No. 25: Yellow Plum × Quarter Century	Plum	Large round	Plum	34	50.0
			Intermediate	125	102.0
			Quarter Century	49	50.0

SUMMARY OF SERIES 5.

Allelomorphs.	Observed Number.	Theoretical Number.
Plum-shaped	121	145.5
Intermediate	326	291.0
Large round	135	145.5
Total	582	.....

Characteristics of parents.—The parents in this series have already been described in previous series.

Results of crossing.—The results of this series are similar to Series 1. The excess of numbers in the intermediate class is due to the

tendency on the part of observers to put all doubtful plants in this class.

SERIES 6.—*Standard height* × *dwarf height.*

Variety crosses.	♀	♂	F_1 hybrids.	F_2 hybrids.	Field count.
Pedigree No. 28: Ponderosa × Quarter Century	Standard height	Dwarf height	Standard	Standard height	144
				Dwarf height	50
Pedigree No. 25: Yellow Plum × Quarter Century	Standard height	Dwarf height	Standard	Standard height	171
				Dwarf height	37

SUMMARY OF SERIES 6.

Allelomorphs.	Observed Number.	Theoretical Number.
Standard height	315	301.5
Dwarf height	87	100.5
Total	402	.....

Characteristics of parents.—Most varieties of tomatoes are of a so-called standard stature, that is, they grow relatively tall. The vines are slender and unless the plant is tied to sticks its weight soon becomes so great that the plant lies prostrate upon the ground.

The dwarf type of tomato, which has already been mentioned as appearing as a mutation, has a very stout, heavy, short stem and a characteristic type of leaf which is crinkly and rugose. This kind is known as *Lycopersicum validum.*

Results of crossing.—The F_1 hybrids resembled the tall parent, except that they were a little taller and more vigorous. The second generation produced talls and dwarfs in the ratio of 3.6:1. The tall and dwarf plants are very distinct. No intermediacy is found. This is a good example of a mutant which Mendelizes with its parental form.

Characteristics of parents.—The red fruits which were used in this series of crosses were of various shades, ranging from blood red to cherry red.[f] The yellows which were also used as types of parents were of a pure-golden yellow color. The color of tomatoes is due to

[f] These colors were described by means of Standard Chart, Repertoire de Couleurs, Paris, 1905

SERIES 7.—*Red fruit* × *yellow fruit.*

Variety crosses.	♀	♂	F_2 hybrids.	Field count, No. of Plants.	Theoretical count.
Pedigree No. 1: Red Pear × Yellow Pear	Red	Yellow	Red	163	170.2
			Yellow	64	56.7
Pedigree No. 4: Red Pear × Yellow Plum	Red	Yellow	Red	188	187.2
			Yellow	62	62.4
Pedigree No. 8: Yellow Pear × Earliana	Yellow	Red	Red	123	105.00
			Yellow	17	35.0
Pedigree No. 12: Yellow Plum × Perfection	Yellow	Red	Red	17	16.5
			Yellow	5	5.5
Pedigree No. 16: Yellow Pear × Trucker's Favorite	Yellow	Red	Red	80	79.5
			Yellow	26	26.5
Pedigree No. 18: Yellow Plum × Stone	Yellow	Red	Red	104	114.0
			Yellow	48	38.0
Pedigree No. 21: Yellow Plum × Earliana	Yellow	Red	Red	38	37.5
			Yellow	12	12.5
Pedigree No. 25: YellowPlum × Quarter Century	Yellow	Red	Red	163	156.0
			Yellow	45	52.0
Pedigree No. 29: Stone × Yellow Pear	Red	Yellow	Red	112	112.7
			Yellow	38	37.2

SUMMARY OF SERIES 7.

Allelomorphs.	Observed Number.	Theoretical Number.
Red	988	978.7
Yellow	317	326.2
Total	1305	....

two factors, the color of the flesh and the color of the skin. The fruits used in the above series had a red flesh with a yellow skin.

Hurst (*Roy. Hort. Soc. Rep.* 3d Inter. Conf. on Genetics, 1906, p. 114) found that when crossing the Fireball tomato with the Golden Queen the Fireball has a red flesh in a yellow skin (RY), and

the Golden Queen has a yellow flesh in a transparent skin (ry). When these were crossed together the F_1 generation hybrid had a red flesh and yellow skin (RrYy) similar to the female parent. When this hybrid was self-fertilized four different types of tomatoes, according to Hurst, were produced, as follows:

(31) Red (Rep. d Col. 81-1)[8] R+Y.
(11) Carmine Red (Rep. d Col. 113-4) R+Y.
(10) Gamboge Yellow (Rep. d Col. 25-4) r+Y.
(3) Sunflower Yellow (Rep. d Col. 23-3) r+y.

Here we see that red color is dominant over yellow and yellow skin is dominant over transparent skin.

Results of crossing.—The results of these hybrids show the same phenomenon that Hurst found, that is, that red is dominant over yellow in the F_1 generation. The colors of the hybrids which are given in the above table were those obtained from the Repertoire de Couleurs chart, and the number which follows the name of the color refers to the number of the page and to the number of the shade on that page in this standard book. It will be seen that the reds which dominate the yellows are of various shades, ranging from light red to dark red, depending probably upon the shade of red possessed by the red parent. In all of the types represented by these crossings a yellow skin was found in every case. In one or two hybrids there could be seen small patches of a pure yellow color around the stem. No irregularity, however, could be found as to the appearances of this yellow color.

In the F_2 generation, the two-colored types again become distinct, in the proportion as shown in the table, namely, 988 reds to 317 yellows.

SERIES 8.—*Red fruit × scarlet fruit.*

Variety crosses.	♀	♂	F_2 hybrids.	Field count.	Theoretical count.
Pedigree No. 26: Red Cherry × Ponderosa..........	Red fruit	Scarlet fruit.....	Red.....................	33	39
			Scarlet.....................	19	13
			Total.....................	52	..

Characteristics of parents.—The variety known as Ponderosa has a color of flesh which is different from the red tomatoes in that it contains much purple pigment in its flesh mixed with the red, forming scarlet. Scarlet is recessive, to red, as seen in the above table.

[8] See Figure I for diagrammatic illustration.

SERIES 9.—*Yellow fruit × scarlet fruit.*

Variety crosses.	♀	♂	F_2 hybrids.	Field count.	Theoretical count.
Pedigree No. 20: Yellow Plum × Ponderosa..........	Yellow fruit.....	Scarlet fruit.....	Scarlet.....................	105	106.5
			Yellow.....................	37	35.5
			Total...	142	....

Characteristics of parents.—In the first generation scarlet is dominant over yellow. A complete segregation occurs in the second generation.

SERIES 10.—*Red fruit, dwarf vine, × yellow fruit, tall vine.*

Variety crosses.	♀	♂	F_1 hybrids.	F_2 hybrids.	Field count.	Theoretical count.
Pedigree No. 25: Yellow Plum × Quarter Century...	Yellow fruit, standard vine.......	Red fruit, dwarf vine	Red fruit, standard vine.......	Red and tall..	136	116
				Red and dwarf	27	37
				Yellow and tall	35	37
				Yellow and dwarf........	10	12
				Total.........	208	....

Results of crossing.—The parents of the above cross have been previously described.

The most important part of Mendelism, from an economic or commercial standpoint, at least, is where more than one pair of allelomorphic pairs are concerned. Upon the segregation of characters and their subsequent recombination hinges the importance of Mendelism from an economic standpoint and also from a scientific standpoint.

As a result of this cross not only the parental types were again produced but two distinctly new forms, namely, tall plants with red fruit and dwarf plants with yellow fruit.

The ratio of the four types produced as compared with the theoretical ratio is very close when the small number of plants is taken into consideration.

Results of crossing.—This cross is very similar to Series 10.

SERIES 11.—*Red fruit, tall vine,* × *scarlet fruit, dwarf vine.*

Variety crosses.	♀	♂	F_1 hybrids.	F_2 hybrids.	Field count.	Theoretical count.
Pedigree No. 28: Ponderosa × Quarter Century............	Scarlet fruit, standard vine.......	Red fruit, dwarf vine.....	Red fruit, tall vine	Red, tall..........	58	63
				Red, dwarf........	20	21
				Scarlet, tall........	26	21
				Scarlet dwarf......	9	7
				Total.............	113	..

SERIES 12.—*Yellow, plum-shaped fruit, tall vine,* × *red, large round fruit, dwarf vine.*

Variety crosses.	♀	♂	F_1 hybrids.	F_2 hybrids.	Field count.
Pedigree No. 25: Yellow Plum × Quarter Century...	Yellow fruit, plum-shaped, tall vine	Red fruit, large round, dwarf vine	Red fruit, intermediate, tall vine.......	Red Plum dwarf......	1
				Red intermediate dwarf................	9
				Red Quarter Century dwarf................	17
				Red Plum tall.........	28
				Red intermediate tall.	89
				Red Quarter Century tall..................	19
				Yellow Plum dwarf...	1
				Yellow intermediate dwarf...............	3
				Yellow Quarter Century dwarf...........	6
				Yellow Plum tall......	4
				Yellow intermediate tall.................	24
				Yellow Quarter Century tall.............	7

PRACTICAL APPLICATION OF MENDELISM

Hybrids are, and have been for many years, an important means of improving plants. The laws of segregation and recombination of hybrids have almost unlimited practical application. The results of these were well known to hybridists long before Mendel's laws were discovered, but the fundamental reasons for them were not known, hence they lacked a scientific definiteness which a knowledge of Mendelism has now brought to them.

At the present time we shall have to be content to direct our attention largely to possibilities and theoretical deductions, because instances of the application of Mendel's laws to economic purposes are rare. This is due to the fact that a definite knowledge of these laws is so recent that these problems have, as yet, not been fully worked out. There are many experimenters in this field, it is true, but it takes a long time to bring such experiments to a stage where they are conclusive and have a direct practical bearing.

Some, however, have been definitely worked out; many others will soon follow. The problem up to the present has been to determine the unit characters in plants and their transmission. Now we are ready for their broad commercial application. These experiments illustrate the working of Mendel's laws and their economic application.

SUMMARY AND CONCLUSIONS

(1) Tomatoes contain numerous separately heritable units which are inherited in alternative fashion without blending.

(2) Some characters such as red and scarlet colors of fruit and tall vines are completely dominant over their allelomorphs.

(3) Such characters as the size and shape of fruit are evidently made up of numerous unit characters. The gross appearance of the F_1 generation is a blend between the parents, but in the second generation types appear forming an almost complete series ranging from the large round parent to the small pear or plum-shaped one.

(4) Dominance and recessiveness depend upon the characters themselves and are independent of the races crossed.

(5) Complete segregation takes place, except possibly where size and shape are concerned, and the actual ratios of types produced are very close to the theoretical Mendelian ratios.

(6) A demonstration is afforded of the economic and commercial use of Mendelism. Desirable unit characters may be transferred from

one plant to another almost at will. Mendelism has an unlimited commercial application.

(7) If a sufficient number of second-generation hybrids are used all possible combinations are produced and no new kinds are found in the third generation. The third-generation hybrids of these tomatoes, the data of which are not presented in this article, prove this.

PRELIMINARY NOTES ON PEPPER HYBRIDS[a]

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In the summer of 1908 a number of races of peppers were grown in the plant breeding gardens at Cornell primarily to observe the varieties and become familiar with the characters presented in order to determine whether this group of plants furnish a favorable field for inheritance studies. Other work prevented the extensive study contemplated, but a few hybrids were made which have since been grown. The second generation of these hybrids produced in the summer of 1910 has given some points of interest and has demonstrated that this is a fertile field of study. It is thought that the notes here presented may be of some interest and may serve in some measure to direct attention more forcibly to the study of what may be termed body characters, such as branching, form of plant, etc.

The races used in the experiments were the commercial sorts known under the names New Celestial, Red Chili, Golden Dawn, Sweet Upright, Dwarf Bell, and Large Bell. The seed used was purchased directly from a seedsman and was supposed to be true to type. In careful experiments it is of course important that seed of known purity be used. The only assurance that the races used in these experiments were pure is found in the fact that the varieties as grown, from 20 to 30 plants of each, were apparently pure so far as could be judged by observation. The attempt was made to obtain inbred seed from each plant used as a parent in order to test its purity, but in the Golden Dawn, one of the parents most used, all of the inbred capsules failed to mature seeds. Inbred seed from plants of Red Chili, New Celestial, Dwarf Bell, and Large Bell used in the experiments in the summer of 1909 produced plants apparently true to type, showing no visible breaking up, and the parent plants were thus judged to be pure in these cases.

[a] Paper No. 21 Department of Plant Breeding, Cornell University, Ithaca, N. Y.

In one case, however, a plant of New Celestial, in the course of the experiments, has been shown to have been heterozygous with reference to at least two allelomorphic pairs, namely, sweet and pungent flavor and the green or yellow coloration of the young fruit.

The analysis of the characters considered in these hybrids is as yet, by no means complete and only by the study of a more extensive series of hybrids can final conclusions and deductions be reached. Such a careful series of experiment on a more extensive scale is now being conducted. The one point that has been most forcibly emphasized in the writer's study of this group is the necessity of a more careful study of individuals than is usually made. In the study of the characters of branching it is necessary to study each individual so carefully that one comes to recognize the individual as we do our human acquaintances by the peculiarities of "facial expression."

Only two series of hybrids will be considered in this paper. These will serve to bring out the characters which it is desired to discuss at this time.

NEW CELESTIAL, FEMALE × GOLDEN DAWN, MALE

These races are markedly different in a number of characters. The following are the characters studied which appear from the results to be allelomorphic:

	New Celestial (female).	Golden Dawn (male).
Branches	Erect	Horizontal.
	Fine	Coarse.
Peduncles	Erect	Reversed.
Fruits	Pungent	Sweet.
Young fruits	Chlorophyll-less (yellow)	With chlorophyll (green).
Mature fruits	Bright red	Yellow.
	Pointed	Blunt (bull nose type).

Aside from the above, which are believed to represent contrasted pairs of characters, several other characters have been studied which show segregation in more or less definite proportions.

F_1 GENERATION HYBRIDS

The first-generation hybrids, of which about 100 plants were grown, were remarkably uniform in character, the variations being no more than would be expected as fluctuations in the various characters in a pure race. The type of branching was in general intermediate

between the two parents, but this character will require further study in the light of hints on the analysis of branching characters obtained in the study of F_2 hybrids. The size of leaves and fruit was also about intermediate between the two parents. As would be expected, all of the plants had red fruits, this character of the maternal parent being dominant over the yellow of the paternal parent. The peduncles were in all cases recurved, this paternal character being dominant. The character of the apex, blunt or lobed as contrasted with pointed, was rather variable, being in general intermediate. The young fruits were green, from the presence of chlorophyll as in the male parent.

The pungency was not tested in all of the hybrids, but this appeared to be a dominant character, marked pungency being found in all plants tested except in one series. In this exceptional case, Series 542a, from one hybrid capsule, of those tested 4 were pungent and 6 sweet. Selfed seed from each of the 6 sweet plants in F_2 gave only sweet plants, while selfed seed of the 4 pungent plants in each case gave both pungent and sweet offspring, showing clearly that the mother parent of this cross was heterozygous with reference to this character though it was in other characters apparently of true New Celestial type.

F_2 GENERATION HYBRIDS

The F_2 generation plants were all grown from selfed seed. In many of the characters studied it was found impossible to group the plants as representing positively one or the other of the characters. They were thus grouped in five classes in such instances, the character as appearing in the male and the female representing the two extremes, with one intermediate class and two gonioclinic classes, representing a greater tendency toward the female on the one hand and toward the male on the other. About 200 hybrids of this combination were grown, but different numbers appear in the case of almost every character studied, owing to unripeness of certain plants at time the notes were taken, injury of plant, or failure to include the character in the observations made. This difference in number in different classes in no way affects the conclusions, though in all cases the numbers are too small.

Leaf size.—In this parental combination the leaves of the female parent, New Celestial, are considerably smaller than those of the male, Golden Dawn. F_2 hybrids apparently show various gradations of size between the parents. In a general grading of size of leaves

the following numbers were obtained in the groups as indicated above: (1) Like mother parent, 4; (2) with decided resemblance to mother, 2; (3) intermediate, 31; (4) with decided resemblance to father, 13; (5) like father parent, 28.

Apparently the father dominates in determining the general size of leaf, but there are many gradations between the two types. The preliminary study indicates that size of leaf here is dependent upon more than one and probably on several factors, the determination of which will require careful statistical study of at least length and breadth in a considerable number of hybrids.

Size of fruit.—In size of fruits the two parents are markedly distinct, those of the mother parent being small in comparison with those of the father. The F_2 hybrids have in general rather large fruits showing a dominating influence of the Golden Dawn. There are, however, many gradations between the two parental sizes. The general sizes were classified as follows: (1) Small like mother, 3; (2) with decided resemblance to mother, 1; (3) intermediate, 50; (4) with decided resemblance to father, 14; (5) resembling father, 30. Here as in leaf size there is a segregation, but size of fruit is evidently not a unit character, and more careful analysis is necessary to determine whether the inheritance can be explanied by Mendelian formulas. In neither leaf size nor fruit size, where we would probably expect to have length and breadth or diameter as at least two distinct allelomorphs controlling general size, does there seem to be an approach to the well known 9: 3: 3: 1 formula.

Fruit color.—The segregation of color in F_2 hybrids is almost absolute; 151 had red fruits and 46 yellow fruits, while 3 were recorded as of intermediate color, being orange-red. Color segregates, therefore, as would be expected in Mendelian proportions. Of the number here concerned, 200, the expected proportion would be 150 red and 50 yellow. If the three orange-red fruits could be classed with the yellows, the expectation would be almost completely realized.

Position of fruit.—With reference to position of fruit, 31 had erect and 48 recurved peduncles. In general the segregation in this character is complete and plainly recognizable, but 5 plants were recorded as intermediate or doubtful. Here the numbers differ greatly from the expected ratio, 21 to 63, and, even assuming that the 5 doubtful plants belonged in the dominant class, the ratio would still be markedly different from the expectation.

Flavor.—In flavor there are apparently different degrees of pungency, but wherever there was noticeable pungency they were recorded

as pungent. Of those on which flavor records were made, 33 were pungent and 10 sweet, which is as near the Mendelian proportion as could be expected. The segregation in this character is very distinct.

Color of young fruit.—In the New Celestial the ovary from the bud to the time of ripening remains yellowish in color, developing no chlorophyll, while in the Golden Dawn the ovary and young fruits up to the time of ripening are green, containing abundant chlorophyll in three or more outer layers of cells. This difference of color apparently depends entirely on the presence or absence of chlorophyll. The F_2 hybrids gave 42 green to 13 yellow, which is almost exactly the Mendelian expectation.

Apex of fruit.—While the apex of the fruit in the New Celestial is pointed and in the Golden Dawn blunt, this character does not appear to segregate in definite proportions. The following are the recorded proportions: pointed like female, 2; mainly pointed like female, 20; about intermediate between pointed and blunt, 14; mainly blunt like male, 25; blunt like male, 27. It is interesting to note that if we take the first two classes as representing the pointed-fruit parent and the last three classes as representing the blunt-fruited parent we have a proportion of 22 to 66, which would be an exact Mendelian ratio if the blunt apex were a dominant character. In the F_1 hybrids the records were: pointed like female, 0; mainly pointed like female, 3; intermediate, 10; mainly blunt like male, 4; blunt like male, 0. It would seem from the F_1 plants therefore that the heterozygous of these characters is in general an intermediate fluctuating more strongly in certain plants toward one or the other parental type. It would not be admissible, therefore, to consider blunt point as dominant.

Our five classes of F_2 hybrids, namely 2–20–14–25–27, would not seem to fall into a Mendelian segregation scheme unless we were to consider the first two classes as pointed, the third and fourth classes as representing the heterozygote plants with reference to this character, and the last class as representing the pure blunt-pointed character. This would give us a formula of 22: 39: 27, which would be as near as we should expect to the Mendelian formula with so small a number. This character, while markedly distinct in the two parents, in the hybrids seems to be mixed frequently on the same plant and difficult to segregate. I am inclined to believe that the plants which are difficult to throw into one or the other of the parental types represent the heterozygous form of these characters.

Form of branching.—The next series of hybrids presents better opportunities to study branching, but the parents in this series differ in at least one or two characters which evidently segregate in the F_2 generation. New Celestial has erect or ascending branches which are rather finer and more numerous than in Golden Dawn. The latter variety in comparison has horizontal or spreading branches which are rather coarser and fewer in number. Of these three character pairs, erect and horizontal segregate the most plainly. Of the F_2 hybrids examined with reference to these characters, 15 had erect branches like the mother; 4, nearly like the mother; 7, intermediate; 3, nearly like father, and 28, like the father. The segregation into fine and coarse branches, placing the individuals in similar classes, gave 2–15–16–8–16. The branches were not sufficiently different in number to permit of segregation into classes. While the segregation classes as given above do not apparently conform to a Mendelian formula, the segregation clearly takes place, which is the most important point. The segregation of erect and horizontal branches, namely, 15-4-7–3-28, would suggest a dominance of the horizontal or spreading type. The segregation of fine and coarse branches, namely, 2–15–16–8–16, suggests a case where the heterozygote is intermediate between the two parental types. The purity of the parents with reference to characters of branching was not determined, and studies of carefully selected pure-bred parental types will have to be made to determine the numerical proportions of the different types.

RED CHILI (FEMALE) × GOLDEN DAWN (MALE)

F_1 GENERATION

The first-generation hybrids of this combination, as in the preceding case, are all very similar and little more variable than a pure race. The leaves and fruits, which in the parental types are markedly different in size, are in F_1 plants about intermediate between the two parents. All had red, pungent, and pointed fruits like the Red Chili and mainly recurved peduncles like the Golden Dawn. There was some variation in this latter character in the F_1 hybrids, which may indicate impurity in the parents used.

F_2 GENERATION

Leaf size.—The difference in leaf size is much more marked in this series than in the preceding, the leaves of the Red Chili being much

smaller than those of the Golden Dawn. Here, as in the preceding series, the F_2 hybrids show various gradations of size between the two parents. The following numbers were obtained in the 5 classes as indicated above: Like mother, 19; with decided resemblance to mother, 22; intermediate in size, 50; with decided resemblance to father, 6; like father, 2. Here, as in the preceding series, Mendelian segregation cannot now be determined.

Size of fruit.—The fruit sizes recorded in the 5 classes as above were 24–20–75–7–3. It is interesting to note that in size of fruit and size of leaf in this combination the largest number approach the female parent while in the preceding series, in which New Celestial was crossed with Golden Dawn, the same male parent being used, the largest number of individuals approach the male parent in size.

Fruit color.—The segregation of color is practically complete, the ratio being 186 red to 41 yellow, only one plant showing an intermediate orange-red color. The proportion of the recessive yellow, here only 18 per cent, is lower than should be expected, but this is probably due to the small number of individuals concerned, there being only 227.

Position of the fruit.—In some instances this character was difficult to determine. Graded in the 5 classes as heretofore, there were 68–5–10–5–21. There were thus 21 with recurved to 68 with erect peduncles in the series as a whole, with 20 plants falling in the doubtful intermediate classes. This would indicate a dominance of the erect fruit or straight peduncle in comparison with the recurved peduncle, which would be the reverse of the preceding series. In the first-generation hybrids there was some variation in this character, and it seems probable that this character may have been impure in one of the parents.

Flavor.—By no means all of the hybrids were tested with reference to this character, but of the 27 tested, which were taken at random, 22 were pungent and 5 sweet, showing segregation in about the ratio we should expect. In both this series and the preceding there would seem to be a preponderance of the pungent individuals, but this probably may be assumed to be due to the small numbers examined in each case.

Apex of fruit.—In the character of the apex of the fruit in this combination we have in the female parent, Red Chili, a more pointed fruit than that of the New Celestial used in the preceding series, and the results of the F_2 segregation are markedly different. Here, graded into our five classes we have 93 pointed like the female; 7 mainly

pointed like female; 15 about intermediate; 4 mainly blunt like male; and 2 blunt like male. In comparing these five classes in the two series of hybrids we have the following:

Series 542, New Celestial pointed (female), 2–20–14–25–27, Golden Dawn (male) blunt.

Series 543, Red Chili pointed (female), 93–7–15–4–2, Golden Dawn (male) blunt.

FIG. 1. FIG. 3.

F₂ HYBRIDS OF RED CHILI ♀ × GOLDEN DAWN ♂.
(All figures of same comparative size.)

FIG. 1. Hybrid with erect, many and fine branches, which may be taken as an extracted type of the maternal parent in these characters and in size.

FIG. 3. Hybrid with erect, few and coarse branches. Like Fig. 2, except in erect branches. Note greater height.

It will be observed that the series are reversed in the grouping of the numbers toward one or the other parent. In Series 542 the blunt apex appears to dominate, while in Series 543 the pointed apex is certainly dominant at least in giving far the largest number of hybrids exhibiting the character plainly. In the discussion of Series 542 with reference to this character it was pointed out that probably the most feasible Mendelian interpretation is reached for the plants in that series by assuming a distinctive heterozygous form represented by classes

FIG. 2. FIG. 4.

F₂ HYBRIDS OF RED CHILI ♀ × GOLDEN DAWN ♂.
(All figures of same comparative size.)

FIG. 2. Hybrid with horizontal, few and coarse branches which may be taken as an extracted type of the paternal parent in these characters and in size.

FIG. 4. Hybrid with horizontal, many and coarse branches.

FIG. 5. FIG. 6.

F₂ HYBRIDS OF RED CHILI ♀ × GOLDEN DAWN ♂.
(All figures of same comparative size).

FIG. 5. Hybrid with horizontal, few and fine branches, giving a dwarf much smaller than either parent.

FIG. 6. Hybrid with horizontal, many and fine branches.

3 and 4, while classes 1 and 2 represented the pointed type; this would give a proportion of 22: 39: 27, which would suggest a Mendelian proportion. It is clear, however, that the 543 series cannot be so interpreted. Here we are led to assume that the pointed apex is a true dominant and that owing to the long slender fruit of the mother producing a much more slender-fruited hybrid the blunt apex is in some measure obscured and that probably all of the classes other than the first or pointed class are to be considered blunt-pointed. This would

FIG. 7. FIG. 8.

F_2 HYBRIDS OF RED CHILI ♀ × GOLDEN DAWN ♂.
(All figures of same comparative size).

FIG. 7. Hybrid with horizontal, few and fine branches. A dwarfish plant, may be heterozygote with reference to few and many branches.

FIG. 8. Hybrid with erect, many and coarse branches, giving a giant plant in comparison with the size of either of the parental types. (Compare with extracted parental types Fig. 1 and 2.)

give us a ratio for Series 543 of 93 to 28, which is near enough to the Mendelian formula for a character pair, where one character is dominant, to satisfy our expectations. Whether this is the true interpretation of the segregation can probably be determined from the study of F_3 generation hybrids grown in the summer of 1911.

Form of branching.—The form of branching in this series furnishes a very interesting study. In general the branches of Red Chili are

erect or ascending, while those of Golden Dawn are horizontal or spreading, and in Red Chili the branches are rather numerous and fine while those of Golden Dawn are few and coarse. It would seem that we have to deal here with at least three character pairs which seem to be primarily concerned in determining what we may term the body form of the plant, namely:

	Red Chili (female).		Golden Dawn (male).
Branches	Erect	or	Horizontal
	Many	or	Few
	Fine	or	Coarse

The F_2 plants of this series, carefully examined and grouped into 5 classes as above with reference to these three allelomorphs, gave the following results:

	Red Chili (female).						Golden Dawn (male)
Branches	Erect	32	4	1	5	16	Horizontal
	Many	24	2	1	2	29	Few
	Fine	27	5	0	10	16	Coarse

The three intermediate classes in the above series, it will be understood, show groupings of plants that seem to be bent in their resemblance more or less markedly toward one or the other parental type of the character. While these proportions are difficult to bring into harmony with Mendelian formulas, the characters show distinct segregation.

The most interesting feature in connection with this series of hybrids is brought out in the recombination of these characters. Both parents are medium-sized types in the pepper group. Apparently, by transferring the character of fine and coarse branches, we create a giant or a dwarf. Hybrids having erect, many, and coarse branches are giants in comparison with the parents, while those having horizontal, few, and fine branches are dwarfs in comparison with the parental forms. Other combinations of the three characters give various forms intermediate in appearance, and without a very careful analysis the hybrids seem to form a graduated series between the parents except that some are smaller and others larger than either parent. It is thought that a more careful study of hybrids from parents known to be genotypic with reference to these three character pairs will enable the investigator to group the plants in accordance with their gametic composition.

In no case which has come under the writer's observation has a more striking instance appeared of the apparent origination of a new char-

acter by hybridization than is found in the giant and dwarf types of this series, and yet by an understanding of the recombination of the branching or body characters of the two parents we apparently arrive at a reasonable and easily comprehended explanation of the origin of the apparently new characters through the recombination of the hereditary units or genes of the parental types.

CARNATION BREEDING[a]

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The original carnation which had been known to history since several centuries before the Christian era, was a five-petal single bloom about an inch in diameter and of a pinkish mauve color. The carnation of today is the product of several centuries of hybridization and culture.

Blooms produced on seedlings vary widely in size, form, and color, and a variety (clonal) once produced from seed is easily perpetuated by propagation from cuttings. The ordinary commercial varieties are of mixed parentage and do not breed true from seed. Improvement in varieties has been brought about by bud variation as well as by seed variation and hybridization.

With our present knowledge of the laws of inheritance in carnations, the production of valuable new varieties is very much a gamble. If the breeder obtains one decided advance in 5000 seedlings, he is very fortunate. Among the most important points to be considered in breeding a valuable commercial type of carnation are the following: (1) Purity and brilliancy of color; (2) strength in calyx to prevent bursting; (3) sufficient length and strength of stem to carry the flower; (4) a well-rounded form evenly divided and with fairly smooth petalage; (5) a pleasant odor; (6) a strong, vigorous habit resistant to disease and capable of producing a continuous crop of flowers; (7) good commercial size.

The tendency to burst does not depend entirely on the strength of the calyx but is influenced greatly by its shape and the manner in which the bloom opens. The number of petals is also an important factor. Flowers in which the petals protrude from the calyx before the bloom opens and then open up on the outside, so to speak, are

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not likely to burst. In other cases, the bursters are such, merely because there are too many petals for the size and strength of the calyx, or, in other words, the flowers are too double.

The technique of cross-pollination is simple. The flowers must be emasculated about the day before they would naturally open. This prevents all chance of self-pollination for the anthers burst some time during the first twenty-four hours after the opening of the bloom. However, the stigma is not receptive at this time, for it takes from one to four days after blooming for it to mature, but as the length of time during which the pollen is potent is not definitely known, it is only possible to do accurate work by the removal of the anthers.

When the pistil is mature (within one to four days or even more after emasculation, depending on the variety and weather) pollen should be applied. The pollen is in condition to use as soon as the anthers open. The best time to do the pollinating is during the middle of the day, on the bright days. The pistillate bloom should be covered continually, from the time of emasculation until the seed is set, if the work is to be on a scientific basis, and it would remove all questions of doubt if the pollen parent were also covered.

In case fertilization takes place, the seed pod should be ready for harvest in about six weeks from the time pollen is applied. Its ripeness is indicated by the drying of the capsule and the loss of its plump, green character.

The best time to breed the carnation from a commercial point of view is in December and January, although the seed may not set as readily as in the brighter, longer days of early spring. The young seedlings can be started early and can be grown and compared outside before the frost comes, thus saving much valuable bench space, which would otherwise be taken up by worthless sorts.

The inheritance of color in the carnation is a subject on which very little has been definitely settled. Mr. C. W. Ward has tried to explain the color of a hybrid lot of plants by the percentage of color found in their ancestors as far back as can be known. In his conclusions, he does not recognize Galton's law or Mendel's principles, and although Mr. Ward is a man of much experience in this work, and has originated a number of the varieties which stand as models of perfection in the American carnation, we can hardly accept his conclusions as representing general laws of color inheritance.

Mr. Fred Dorner gives the following results in regard to color inheritance: Pure white is secured by working pure white on white; yellow by working yellow with yellow or white; yellow with scarlet will inten-

sify the scarlet or may produce deeper yellow or orange; scarlet with crimson intensifies crimson and gives the scarlet maroons; all shades of pink may be used together, but for the development of clear pink all those with scarlet or mauve undertones are not to be used; all pinkish lavenders, mauves, and purples are kept in a class by themselves and should not be used with other colors, as they dull them. The above rules, so to speak, have been worked out after careful study and wide experience. However, no explanation of the same is offered. Future study of the color inheritance of the carnation will likely result in findings similar to the inheritance of color in the sweet pea.

The form of the carnation bloom, according to the evidence of the experiments carried on by J. B. Norton, seems to follow Mendel's law. That is, the single and the very double types (bullheads) are pure and will come true to seed, while the standard form is the result of hybridization, and is the "hybrid form," or intermediate between the two parents. This is again seen when the two standards are bred together, for about 25 per cent of the offspring will be single, 25 per cent bullheads, and 50 per cent standard.

Carnation Hybridization Studies by the Author.—In the spring of 1908, at the suggestion of Mr. Norton, hybridization was started on a limited scale, to check up on some of the Mendelian theories concerning the inheritance of form.

The objects in view were to determine, if possible, if the standard carnation is a heterozygote or hybrid form; if the single is a pure recessive and if the "bullhead" is a pure dominant.

The single carnation has, as a rule, five petals, but a few exceptions have been noted in which four and six petals were present.

The form classified as standard is the commercial type having from 30 to 60 petals, varying among the varieties.

The bullhead is the extreme double, which generally bursts its calyx in opening and oftentimes has vestiges of aborted ovules. The number of petals will range from 100 to 350.

To make these determinations, singles were bred with singles; singles were bred with standards; singles were bred with bullheads; and standards were bred with bullheads.

The plants used in this work were mainly seedlings produced by Mr. William Alderman. These seedlings were all produced from standard parents. Therefore, to further check Mr. Norton's work, these seedlings were also classified into the three following classes: Singles, standards and bullheads.

There was a total number of 45 seedlings. The following table

shows the actual result and the result to be expected if these seedlings were to follow in definite Mendelian ratio.

TABLE 1.—*Total number of seedlings 45, from standard stock.*

	Single.	Standard.	Bullhead.
Actual result.......	9	28	8
Expected result ...	11.25	22	11.25

In consideration of the small population, I believe the actual results are as near the theoretical as would naturally be expected.

The following table shows the result of the crosses and expected result:

TABLE 2.

	Actual result.	Expected result.
Single × single (total 32):		
Single..	32	32
Single × standard (total 59):		
Single..	29	29.5
Standard....................................	30	29.5
Single × bullhead (total 52):		
Standard....................................	52	52
Standard × bullhead (total 11):		
Standard....................................	7	5.5
Bullhead....................................	4	5.5

From the above tables, in consideration of their limited numbers, it would seem that Mr. Norton's assumption that the standard Carnation is a hybrid in form and can never be fixed is a well-founded conclusion. If this is correct, a so-called "standard" variety of carnation which will breed true from seed is as impossible as the production of a pure strain of "Andalusian fowl."

From the results of Table 2, it is seen that the single carnation behaves as a pure recessive, as when singles were bred together, even though they were of double parentage, the resulting seedlings were 100 per cent single.

When the single form was bred with the standard, which, according to previous experiments, seemed to be heterozygous for form, the seedling plants proved to be 29 single and 30 standard. This is exactly as would be expected when a pure recessive is crossed with heterozygous forms.

When singles were crossed on the bullhead form, all the resulting seedlings were of the standard type, as the blue Andalusian fowl is produced by crossing together the white and the black forms.

While the first indications seemed to denote that the form of the carnation follows Mendel's law of dominance, further study was carried

on to see if there might be a blending of inheritance in the number of petals, which is the main factor which determines the class the individual shall fall in, be it single, double, or bullhead. With three exceptions, all the singles I have ever noted have had five petals, the exceptions had four and six. The number of petals in a standard variety no doubt varies somewhat with the cultural conditions, etc., but the average range, taking the varieties as a whole, will fall somewhere between 30 and 60 petals, while the typical bullhead ranges between 100 and 350 petals.

The petals were not counted in any of the parents of the seedlings mentioned in the above or following tables. However, the seedlings were examined to determine if possible if there was any relation between the number of petals in the hybrid to the probable number in the parents. In other words, we endeavored to find out if there was simply a blended inheritance in form of the carnation with only one pure form, the single, and all the doubles, both standard and bullheads, existing as heterozygous.

The following table shows the results:

TABLE 3.—*Average number of petals in blooms produced from various crosses.*

	Number of petals.
Single × single	5.03
Single × standard	44.30
Single × bullhead	87.20
Standard × bullhead	130.00

The average number of petals in this crop of bullheads was 183.

From the above table it would seem that doubling of the carnation bloom may be dependent upon more than one set of allelomorphic factors, and that there is likely to be a certain interaction of factors seems probable.

The work of Norton as far as carried out seemed to agree very closely with the results in the preceding tables. In crossing singles with bullheads, 249 standards were obtained and one single. Mr. Norton believes that this single could be accounted for by the fact that the blooms were not covered.

In Dr. H. J. Webber's experience with a lot of seedling carnations started by Norton, the results were rather unexpected in view of the previous investigations noted above. Dr. Webber found in crossing the single on bullhead, among 114 seedlings, that 5 were single, 104 were standard, and 5 bullhead.

In discussing the results, Dr. Webber writes as follows:

It will be seen from these results that of the 114 crosses of single with bullheads 104 were standards, 5 singles, and 5 bullheads. In general, this would seem to uphold the claim that the standard is a heterozygote form, but it is difficult to account under this interpretation for the 5 singles and 5 bullheads. My understanding is that the original hybrids were made without bagging, and while very little natural pollination takes place in greenhouses these may be explained as impurities in pollination. In this way we may easily account for the singles, as there were many singles grown in the house where the hybridizations were made, and singles crossed with singles give singles. It is much more difficult, however, to understand how the bullheads could have resulted from such accidental combinations. The pollen, entering as an impurity, would from necessity have to come from singles, standards, or bullheads. If it came from the singles, all should have been singles. If from standards, all should be either singles or standards. And if from bullheads, all should be standards. Thus, no interpretation of impurity in pollination merely explains why we should get some bullheads from this combination. I am inclined to the opinion that these apparent impurities, both of singles and bullheads, represent the possible variations in the heterozygous form.

There is a decided tendency for the heterozygous form to fluctuate rather close to the single form. In the opposite direction, the same variation exists. In series 6, one seedling classed as a standard was recorded as a semi-bullhead In series 12, two seedlings classed as standards were recorded as semi-bullhead. In series 21, the single seedling classed as a bullhead was recorded as "not a full double." These observations indicate, therefore, that the fluctuation of the heterozygote is also in some instances markedly toward the bullhead parent. The numbers here concerned are too small to enable one to deduce conclusions with any degree of certainty or probability, but the figures suggest that we may be dealing here with the presence and absence of a character, namely, doubleness and absence of doubleness. In the F_1 generation, where single is crossed with full double (bullhead), only one determiner for doubleness would be present. This, we may assume, manifests its presence in a strength weaker than when two determiners are present, giving usually a degree of doubleness about intermediate between the two parental types, but exhibiting marked fluctuation towards one or the other parent. In a few cases, the influence of the one determiner may be considered to be very ineffective and weak, when flowers single or nearly single would be developed. In other cases, we may assume that the one determiner is very strong and potent and gives nearly full double flowers similar to the bullheads. If this interpretation holds good that the phenomena of the appearance of a few singles, or nearly singles, and full doubles or nearly full doubles, is due to fluctuations in the activity or strength of the one determiner for doubleness present in the heterozygote form, then such extreme fluctuations toward singleness or doubleness would exhibit their hybrid composition with reference to doubleness in further experiments by self-fertilization or crossing with other plants of known gametic purity. Such trials have not been made in our experiments, and I give the suggestion for what it may be worth. Some of your crosses may give further proof on this point.

Whatever truths may be developed in the future concerning the interaction of Mendelian factors or the fluctuating variability of

carnation hybrids, there are a few practical hints which can be gleaned by the commercial breeder from the aforementioned investigations. As noted from this work, the single or the extreme double carnation may be of great value in breeding work in spite of the fact that as a commercial individual, it is worthless.

If the desired color and plant characters are obtained in individuals with either one of these bloom characteristics, they can be easily recombined in a hybrid of normal standard form and henceforth be propagated by cuttings as is customary. Oftentimes, very desirable hybrids are produced except for the tendency to burst, which is due to an excessive number of petals. If such a seedling is crossed with a single of the *same color* and with equally desirable plant characters, our experience has shown that a number of offspring may be expected with the same sort of plant and flower color characters, but with fewer petals, thus avoiding the likelihood of bursting.

THE EFFECT OF TEMPERATURE ON STELLARIA MEDIA

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Reinöhl[a] concludes from his extensive observations on *Stellaria media* that light and nutrition have a marked influence on the number of stamens produced and that temperature has very little if any. His results show that reduced light gave a decided mode at 3 while unreduced light shifted the mode to 5. This was equally true with diminished and excessive food supply; but his temperature investigations led him to conclude that increased temperature caused no such change.

The temperature populations in Reinöhl's studies were taken in the field in early spring, in midsummer, and in autumn. There is no very marked difference in the distributions of the three populations, but the mode is slightly less prominent at 3 in the summer population than in either of the others. In all three cases the principal mode is at 3 with a second but lesser one at 5. In no case did he find a population with its mode at 4.

Martens and Kemmler[b] find 5 to be the normal number of stamens in this species but that spring populations often produce three-stamen

[a] Reinöhl, F. Die Variation im Andröceum der *Stellaria media*. *Bot. Zeitung*, 61: 159–200 (1903).
[b] Martens and Kemmler. *Flora von Württemberg und Hohenzollern*. S. 60 (1882).

flowers as the common type. H. Müller[c] shows that 3 and 2 are the usual number in fall and winter but that 5 and 4 are produced more commonly in the spring.

The results presented in this paper are especially interesting in view of these different observations. The data were taken on plants grown in greenhouses maintained at different temperatures, and are but preliminary to a study of the effectiveness of adverse conditions of temperature in causing variation and in producing mutations.

Stellaria media is a valuable plant to experiment on because of its hardiness and its rapid reproduction, since it is possible to grow three generations in one year.

The seeds of two pure lines (second generation) were germinated in October and November, 1910, under controlled conditions. When the young seedlings contained from 6 to 8 leaves they were transplanted into 4-inch pots. The soil was all obtained from a common supply and thoroughly mixed. All plants were watered uniformly and the temperature maintained as nearly constant as possible, the mean temperature being 63°F.

A careful count was made of the number of stamens and petals as the flowers appeared and a pedigree record kept of each plant. This was done to make a comparison of the parents, which were to be later treated to freezing temperatures, with those of their offspring,

At the same time a mixed population was grown in an adjoining room, kept at 54°F, as material for study. As soon as the pure-line plants became well established vegetative cuttings were made from them by severing from the parent plant young branches, which had taken root at the nodes, sufficient soil being retained on the roots to prevent the checking of growth when transplanted into new pots. These cuttings were transferred to the colder house.

In making the counts of stamens of the pure lines in the warm house it was evident that there was a much larger number than in those of the mixed population in the cold house.

The question then arose as to whether this difference was due to the difference in temperature or to the fact that genotypes, with an increased number of stamens, had been isolated.

As soon as the young pure-line cuttings had begun to bloom freely (thirty days after transplanting) a count of the flower parts of the pure-line population, which had been transferred to the cold house, was begun. At the same time the counting in the warm house, as well as that on the mixed population in the cold house, was continued.

[c] Müller, H. Weitere Beobachtungen ü. Befruchtung der Blumen durch Insecten. *Verhandl. d. Naturhist. Vereins d. preuss. Reinland u. Westfalens*, 36: 228 (1879).

The results are given in the following tables and in the graphic representations:

TABLE 1.—*Showing number and percentage-frequencies of stamens in Stellaria media.*

The row across the top gives the number of stamens. The first row in each section gives the number of flowers and the second row gives the percentages of flowers occurring in each class.

	Designation of line.	0	1	2	3	4	5	6	7	8	9	Total.
PART 1.												
Greenhouse (63° F.)	A				48.0	104.0	127.0	2.0				281
					17.08	37.01	45.20	0.71				100
	B			2.0	71.0	102.0	52.0					227
				0.88	31.28	44.93	22.91					100
	C (A and B)			2.0	119.0	206.0	179.0	2.0				508
				0.39	23.43	40.55	35.24	0.39				100
PART 2.												
Greenhouse (54° F.)	A				91.0	67.0	56.0	4.0				218
					41.74	30.73	25.69	1.83				100
	B			8.0	64.0	3.0	1.0					76
				10.53	84.21	3.95	1.32					100
	C (A and B)			8.0	155.0	70.0	57.0	4.0				294
				2.72	52.72	23.81	19.39	1.36				100
PART 3.												
Greenhouse (54° F.)	A and B			14.0	372.0	193.0	123.0	5.0				707
				1.98	52.62	27.30	17.40	0.71				100
PART 4.												
Greenhouse (63° F.)	A				9.0	23.0	24.0	1.0				57
					15 79	40.35	42.11	1.75				100
	B			1.0	21.0	29.0	13.0					64
				1.56	32.81	45.31	20.31					100
	C (A and B)			1.0	30.0	52.9	37.0	1.0				121
				0.83	24.79	42.98	30.59	0.83				100
PART 5.												
Greenhouse (54° F.)	Mixed	1.0	6.0	81.0	1838.0	625.0	243.0	6.0	1.0			2801
		0.04	0.21	2.89	65.62	22.31	8.68	0.21	0.04			100
PART 6.												
Field	Mixed			3.0	167.0	307.0	579.0	122.0	29.0	14.0	4.0	1225
				0.24	13.63	25.06	47.27	9.96	2.37	1.14	0.33	100

By examining Table 1, part 1, it will be seen that pure line A when grown in the warm house (63°F) produced 45.20 per cent of its flowers with 5 stamens, 37.01 per cent with 4, 17.08 per cent with 3, and 0.71 per cent with 6 stamens.

Pure line B when grown in the same house produced 44.93 per cent of its flowers with 4, 31.28 per cent with 3, and 22.91 per cent with 5 stamens. When the counts from the two lines were thrown together more than 40 per cent are found at 4, 35 per cent at 5, and 23 per cent at 3.

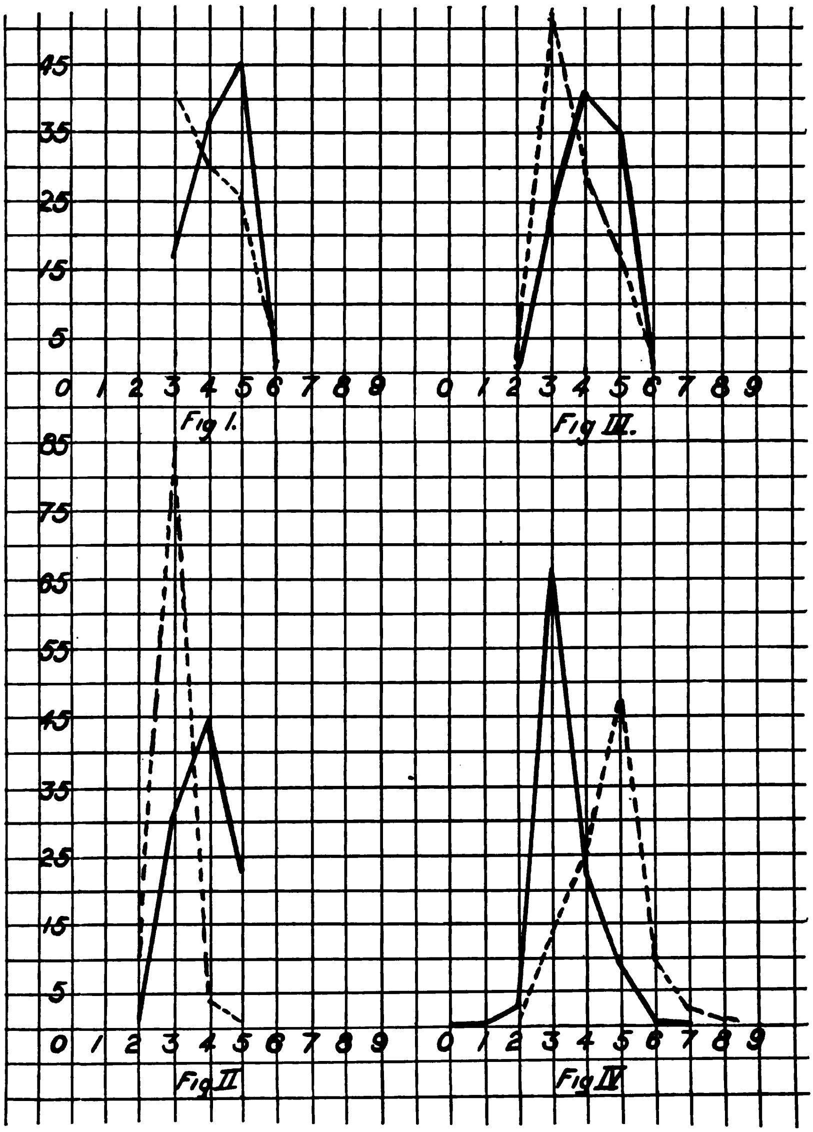
In Table 1, part 2, it will be seen that when line A was transferred to the cold house, the greatest frequency was changed from 5 to 3, there being now nearly 42 per cent of the flowers at 3, as compared with 17 per cent in the warm house; the number at 5 is reduced from 45 per cent to 26 per cent. Although this marked shifting has occurred the range of variation has remained constant, both in extent and in the classes it includes.

In line B there is even a more marked shifting, there being now 84 per cent of the flowers with 3 stamens as compared with 31 per cent in the warm house; 3.95 per cent at 4 as compared with 44.93 per cent, 1.32 per cent at 5 as compared with 22.91 in the higher temperature; probably the greatest change is in the reduction of 4's and 5's. In this line as in A the range of variation is absolutely constant under both conditions.

In Table 1, part 3, are included the individuals in A and B of Table 1, part 2, plus 413 flowers counted on the same plants before the pedigree record keeping was begun on them. A comparison of this table with C of Table 1, part 2, shows that the two tables correspond almost exactly, so that with the two counts combined there is practically the same number in the population as in that of the warm house, and yet it shows clearly a distinct shifting of the mode.

In Table 1, part 4, are given the results obtained from counts on a number of the vegetatively propagated plants grown along with those in the cold temperature but again transferred to the warm house after the taking of data on the plants in the cold house had begun. No results were recorded until an entirely new set of buds were formed under the changed conditions. The season was so far advanced when these counts were made that the population is small but nevertheless significant. We have here in line A a complete reshifting of the mode back to its original position. The same is true of line B. The percentages are again approximating those of the original populations. Here again we have that striking constancy of these pure lines in remaining within their normal range.

The results of data taken on the mixed population in the cold house are given in Table 1, part 5. Here the mode is at 3, there being nearly 66 per cent of the total in this class. While the population is much



CURVES REPRESENTING THE DIFFERENT POPULATIONS OF STELLARIA MEDIA.

FIG. 1. The continuous curve represents line *A* in the warm house. The dash curve represents line *A* in the cold house.

FIG. 2. The continuous curve represents line *B* in the warm house. The dash curve represents line *B* in the cold house.

FIG. 3. The continuous curve represents the combined lines *A* and *B* in the warm house. The dashed line represents the same lines in the cold house.

FIG. 4. The continuous curve represents the mixed population in the cold greenhouse. The dashed line represents the mixed population in the field.

larger than that of either of the pure lines, yet when the total number in both lines are thrown together they still show this marked constancy.

The stamens of a mixed population in the field were counted from April 8 to 12, the results of which are recorded in Table 1, part 6. The mode is at 5, with a fairly equal distribution on each side, although the greater number is at the left. The range is very great in comparison with the pure lines. I shall not attempt to explain the cause of the great difference between the mixed population in the greenhouse and that in the field, because in these we have too many complicated factors to deal with. For instance, we do not know when the stamens of the field populations were really formed. Many of them had undoubtedly passed through the winter in the bud. This was shown by the color, texture, and mutilation of portions of the buds.

TABLE 2.—*Constants of the various temperature populations.*

Population.	Mean.	Standard deviation.	Coefficient of variability.
I A	4.2954 ± 0.0302	0.7509 ± 0.0214	17.4815 ± 0.5124
II A	3.8761 ± 0.0381	0.8340 ± 0.0269	21.5165 ± 0.7265
I B	3.8987 ± 0.0337	0.7528 ± 0.0238	19.3090 ± 0.6336
II B	2.9605 ± 0.0342	0.4425 ± 0.0242	14.9468 ± 0.8359
I C	4.1181 ± 0.0233	0.7773 ± 0.0164	18.8752 ± 0.4134
III	3.6223 ± 0.0207	0.8155 ± 0.0146	22.5133 ± 0.4238
V	3.3702 ± 0.0090	0.7063 ± 0.0064	20.9572 ± 0.1969
VI	4.6637 ± 0.0198	1.0267 ± 0.0140	22.0147 ± 0.3142

A study of the curves and the arrays in the tables shows some very interesting phenomena with respect to skewness. The four curves at the left in plate I represent the pure lines, those in Fig. 1, representing line A and those in Fig. 2, line B. The continuous curve in each figure is the representation of the populations of the warm house and the dashed curve those of the cold house. The combined pure lines are represented in Fig. 3, the continuous curve representing those of the higher temperature and the dashed curve those of the colder temperature. The mixed populations are represented in Fig. 4, the continuous curve representing the greenhouse population and the dashed curve the field population. A decided negative skewness is shown in A, in the warm house (see fig. 1), 45.2 per cent of the individuals falling in class 5, while only 0.71 per cent lie above this class. But when this same line was transferred to the colder house it gave a skewness in the opposite direction (fig. 1). The transformation is very marked. It is also of interest to note that the curve ends very abruptly on the lower side, there being 41.74 per cent in class 3 and

not a single individual in class 2. This latter fact was quite striking in the high temperature population (the same pure line). A more nearly normal curve is formed in line B. The modal class was entirely shifted from 4 to 3, the curve still retaining about the same form (fig. 2). The curve for the combined pure lines is almost normal, with its mode at 4; but the same lines when grown in the colder house show a very marked shifting from 4 to 3 and a decided positive skewness (fig. 3). The curves of the two mixed populations are very different; the greenhouse population gives a curve with its mode at 3 but with a decided positive skewness; the field population, on the other hand, forms a curve with its mode at 5 and with a slightly negative skewness.

In comparing the constants (see Table 2) it is found that the mean, standard deviation, and coefficient of variability (except in III), are all greater in the field population than in any of those grown in the greenhouses. This is probably due to the presence of a greater number of biotypes and to a greater diversity of environmental factors operating. The standard deviation and the coefficient of variability are smaller, in the population of the combined pure lines when grown in the higher temperature, than in that of the same lines grown in the lower temperature; but the mean is much larger. A comparison of the two populations of line A shows an increase in the mean under the higher temperature conditions, but a marked decrease in the standard deviation and the coefficient of variability. The reverse conditions for the standard deviation and coefficient of variability are shown in line B. It seems that the two lines react differently to the same conditions.

To bring out the relation of pure lines to the variation of an ordinary population of plants, the curves should be studied with this special point in view.

In explaining the narrow, fixed range of each pure line three points should be considered: first, the law of chance; second, the uniformity of environmental conditions; and, third, internal causes. The first point may be answered by saying that the numbers are sufficiently large to eliminate the law of chance. The two lines together represent approximately 1200 individual flowers, while the mixed population from the field produced about 1200, and yet in the latter the range includes 8 classes and in the former only 5. The second point may be disposed of by comparing the mixed population in the greenhouse with the two pure lines. The range in the former includes 8 classes as compared with 5 in the latter, and yet both were grown in the same house. Change of temperature caused an internal shift-

ing and rearrangement of the arrays but did not alter the range. Certainly, then, chance alone cannot account for the narrow fixed range of these pure line plants, nor can the conditions under which they were grown, but we must turn to some internal cause. Probably the key to the situation lies within the plant itself. The most plausible explanation seems to be that, in isolating these pure lines, two distinct "genotypes" were the result. This idea is further borne out by the fact that the mixed populations of the greenhouse show the same range (in extent) as that of the field population, notwithstanding the marked difference of variability in other respects.

SUMMARY AND CONCLUSIONS

The foregoing discussion may be summarized as follows:

(1) A difference of opinion exists as to the effectiveness of temperature in modifying the morphology of *Stellaria media*.

(2) All previous temperature observations on Stellaria referred to were made on populations grown under uncontrolled conditions.

(3) The two pure lines isolated in my experiment seem to be distinct genotypes.

(4) The lines reacted differently to changes of temperature but both responded readily to such changes.

(5) The field population gave larger constants than any of the populations grown in the greenhouse.

(6) The mixed population in the greenhouse showed a much wider range of variation than did either or both of the pure lines, and yet the standard deviation and the coefficient of variability are smaller than those of the combined pure lines.

(7) The range of variation within the pure lines was not increased, in spite of the fact that there were marked internal shiftings.

(8) In each of the pure lines there was a changing from negative to positive skewness upon being transferred from higher to lower temperature.

(9) The variations of a mixed population are due to differences in environmental conditions, including nutrition, light, temperature, etc., and probably to internal variations. But the difference in the extent of range is due principally to internal causes; or, in other words, increased range is due to increased number of biotypes present.

(10) These experiments were all conducted under controlled conditions, excepting the one field population, and the populations were sufficiently large to indicate some interesting lines of investigation.

REPORT OF THE COMMITTEE ON BREEDING TREE AND VINE FRUITS

PROF. S. A. BEACH, *Ames Iowa*, Chairman

PROF. W. T. MACOUN, *Ottawa, Canada.*
PROF. U. P. HEDRICK, *Geneva, New York.*
PROF. R. S. MACKINTOSH, *Caledonia, Minnesota.*
LUTHER BURBANK, *Santa Rosa, California.*
W. T. SWINGLE, *Washington, D. C.*
DR. T. V. MUNSON, *Denison, Texas.*

In 1909 the chairman of this committee presented to the Association a statement concerning the present status of apple breeding in America. It is gratifying to report that in general the interest in this line of work is being well maintained and that good progress is being made. It is hoped that similar reports concerning other tree fruits and the vine may be prepared.

The committee is proposing also to present reports indicating the more important problems in the breeding of tree and vine fruits which need to be worked out in the various parts of the country. The first contribution of this kind is presented below. It is from the veteran grape breeder, T. V. Munson.

PROBLEMS IN BREEDING TREE AND VINE FRUITS

T. V. MUNSON

Denison, Texas

The main direction to be pursued in breeding tree and vine fruits is to ascertain the best elements to be used as parents, so as to secure in the progeny the desired results, and this requires:

(1) The greatest degree of *adaptation* to climate for which intended.
(2) *Adaptation* to special soils.
(3) *Resistance* to destructive fungus and insect enemies.
(4) Vigor and longevity.
(5) Certainty and prolificacy of bearing.
(6) Size and beauty of product.
(7) High quality.
(8) Best handling and shipping properties.
(9) Most important of all combination of greatest number of above eight points.

For the region of North Central Texas and South Oklahoma the special requirements would be—

(1) Capability of thriving under great and sudden changes of temperature, and of humidity and aridity of atmosphere and soil.

(2) (a) Some varieties to very limy soils; (b) others to very sandy soils. Few are found equally adapted to both.

(3) There is room for much work in improving varieties especially adapted to this region in every class of fruits, as the work of originating varieties especially adapted to it is in its infancy.

MENDELIAN INHERITANCE IN PRUNUS HYBRIDS

S. A. BEACH AND T. J. MANEY

Ames, Iowa

The following data are offered as a contribution to our knowledge of Mendelian inheritance in Prunus hybrids. Brief notes on the correlation of certain characters are also given. Although these data do not supply a sufficient basis for the demonstration of conclusive results, they do in some instances give striking indications of the operation of Mendelian factors.

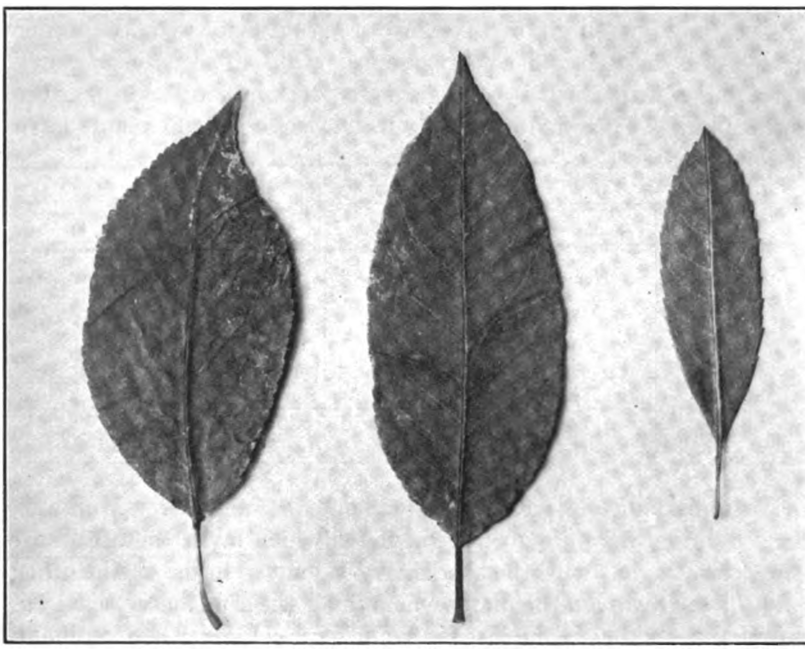
Material under investigation.—The material under observation consists of two general classes of F_2 Prunus hybrids produced by unguarded F_1 parents. One class is composed of sandcherry-cherry hybrids, the other of sandcherry-plum hybrids.

The sandcherry-cherry hybrids, *Prunus besseyi* × *Prunus cerasus*, consist of F_2 plants from seed of the Montbesseyi, which is a named horticultural variety produced by Theo. Williams, Benson, Nebr., by cross-pollinating the western sandcherry, *Prunus besseyi* Bailey, with pollen of the Montmorency, a horticultural variety of the common garden cherry, *Prunus cerasus* Linn. The forms of leaf of Montbesseyi and its parents are shown in figure 1.

The sandcherry-plum hybrids, *Prunus besseyi* × *Prunus americana*, consist of F_2 plants from seed of F_1 hybrids known as Wagner Nos. 2, 4, and 6. These were originated by J. F. Wagner, Bennett, Iowa, by pollinating the Dwarf Rocky Mountain cherry of Pennock, a horticultural variety of *P. besseyi*, with pollen of the Wyant plum, a cultivated variety of the native *P. americana*. The forms of leaf of these Wagner Nos. 2, 4, and 6 and their parents are shown in figure 2.

As has been remarked, the F_2 plants above mentioned all came from F_1 unguarded parents, which fact introduces an element of uncertainty into the interpretation of the results. But the populations under

observation are so large that it is probable that the general averages do not differ greatly from those which would have been found with corresponding populations from guarded seed. The general character of the different sets of plants mentioned is such as to support this opinion. The results are all of interest from the Mendelian point of view. Those on immunity from aphis are especially significant to practical plant breeders as bearing upon the question of breeding varieties of plants possessing immunity from certain insect pests.



Montmorency. Montbesseyi. P. Besseyi.

FIG. 1. LEAF FORMS OF MONTBESSEYI AND ITS PARENTS.

In view of all these considerations and of the fact that the production of new sets of plants from guarded seeds and the development of them to the age of those used by the writers would require six years or more, it has seemed best to present a preliminary report at this time. This is done with the hope that it may help to interest others in the matter of Mendelian characters in Prunus hybrids.

Characters observed.—Observations were made on the inheritance of the characters of color of foliage, form of leaf, persistence of stipules, habit of tree growth, and immunity from plant lice. The correlation of certain characters was also noted.

In studying the different characters the population was generally classified into these four groups:

(1) Individuals most closely approximating the type of the mother P_1.

(1a) Intermediates which most favor the mother type P_1.

(2a) Intermediates favoring the male parent P_1.

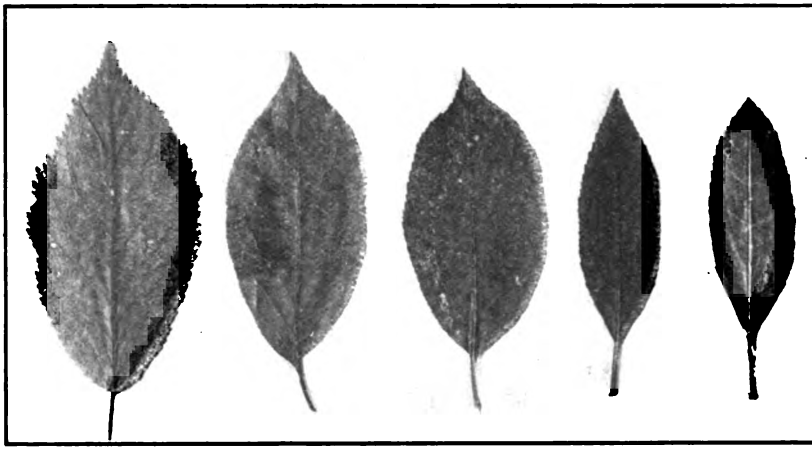
(2) Individuals most closely approximating the type of the male parent P_1.

Color of foliage.—The sandcherry is characterized by foliage having a rather pale green, glabrous, shiny upper surface, with the under surface of a lighter and softer greenish gray. The Montmorency cherry has a leaf which is comparatively dark green, as also has the Wyant plum. Classified according to leaf color, the F_2 plants gave the following records:

Group.	Sandcherry × Montmorency, F_2.		Sandcherry × Wyant, F_2.	
	Number.	Per cent.	Number.	Per cent.
1	44	34.2	31	24.8
1a	50	38.7	..	....
2a	..	....	50	40.0
2	35	27.1	44	35.2
Total populaton	129	....	125	....

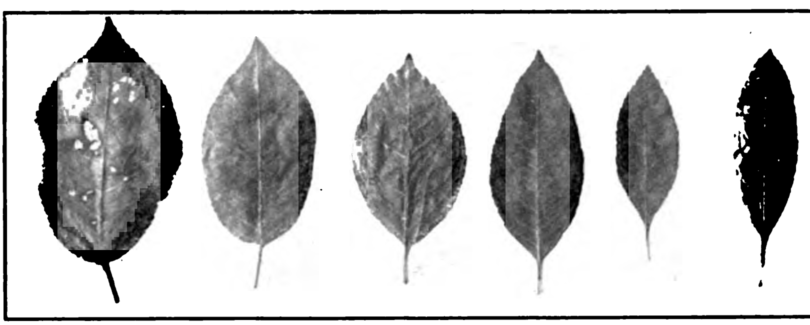
It is remarkably interesting that among the sandcherry-Montmorency hybrids there are no intermediates which favor the Montmorency, class 2a, but with the sandcherry-Wyant hybrids, on the other hand, there are no intermediates which favor the sandcherry, class 1a. Thus it appears that in one case the sandcherry color is either dominant or imperfectly dominant and the cherry color is distinctly recessive, while in the other case the plum color is either dominant or imperfectly dominant and the sandcherry color is distinctly recessive. In both hybrid groups there was a clear demarcation between the recessives and the dominants or imperfect dominants.

Form of leaf.—Inheritance of form in the leaf was studied by comparing the F_2 Prunus hybrids with their F_1 parents and more especially with their grandparents, the sandcherry and the cherry or the sandcherry and the plum as the case might be. This showed at once that in these plants the form of the leaf is determined neither by a single factor nor by any set of factors combined together so as to act as a unit. It was found, for example, that an F_2 hybrid might have the



Wyant. Wagner No. 2. Wagner No. 4. Wagner No. 1. P. Besseyi.

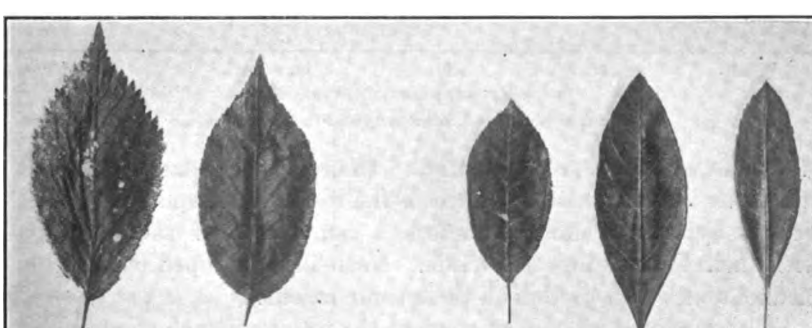
FIG. 2. LEAF FORMS OF WAGNER HYBRIDS AND THEIR PARENTS.



Montmorency. 2a. 2. 1a. 1. Sand Cherry.

FIG. 3. PRUNUS BESSYI × MONTMORENCY.

Base forms of leaves of Montmorency and Sandcherry, and their Hybrids.

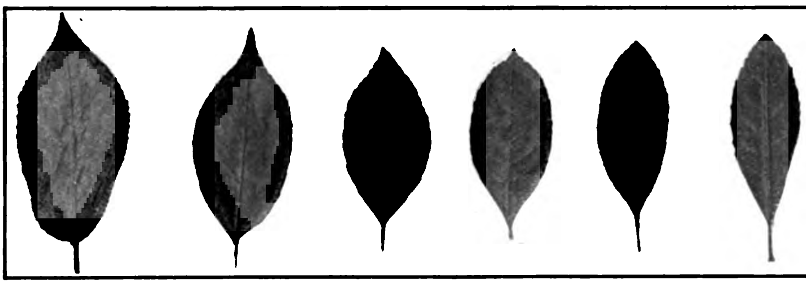


Wyant. 1. 2a. 2. Sand Cherry.

FIG. 4. PRUNUS BESSYI × WYANT F_2.

Base forms of Wyant, and Sandcherry and their F_2 Hybrids.

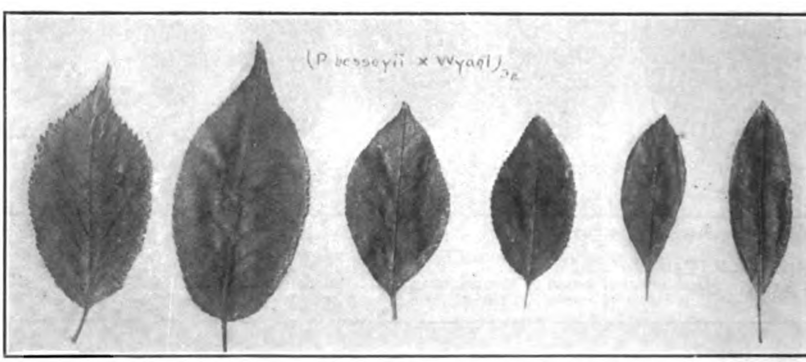
characteristic tip of the Wyant leaf combined with a base similar to that of the sandcherry, or vice versa it might resemble Wyant in base and the sandcherry in tip, or again it might show intermediate forms in either base or tip. In like manner other parts of the leaf might resemble the plum in one particular and the sandcherry in another. Similar recombinations were found in the sandcherry-cherry hybrids. All this is evidence that the ultimate form of the leaf is the resultant



Montmorency. 2. 2a. 1a. 1. Sand Cherry.

FIG. 5. PRUNUS BESSYI × MONTMORENCY F_2

Tip forms of Montmorency and Sandcherry and their F_2 Hybrids.



Wyant. 2. 2a. 1a. 1. Sand Cherry.

FIG. 6. PRUNUS BESSEYI × WYANT F_2.

Tip forms of Wyant and Sandcherry and their F_2 hybrids.

of various separable growth factors. In order to get data as to what characters entering into the form of the leaf are transmitted in these Prunus hybrids as unit characters, a comparison of the F_2 plants with their F_1 ancestors was made. Normally developed leaves from median nodes were used in all these comparisons.

Following is an account of some of the results of such comparison:

Base of leaf.—The base of the sandcherry leaf is characteristically different from that of either the Montmorency cherry or the Wyant

plum, as is shown in figure 3 and figure 4. It is narrow and makes an acute angle with the petiole, while that of the Montmorency is rounded and blunt and that of the Wyant varies from roundish to a nearly 60° angle.

The following table shows the classification with respect to the form of the base of the leaf:

Group.	Sandcherry × Montmorency, F_2		Sandcherry × Wyant, F_2.	
	Number.	Per cent.	Number.	Per cent.
1	39	30.2+	25	20.0
1a	30	23.2+	18	14.4
2a	28	21.7+	..	....
2	32	24.8+	82	65.6
Total population..	129	....	125	....

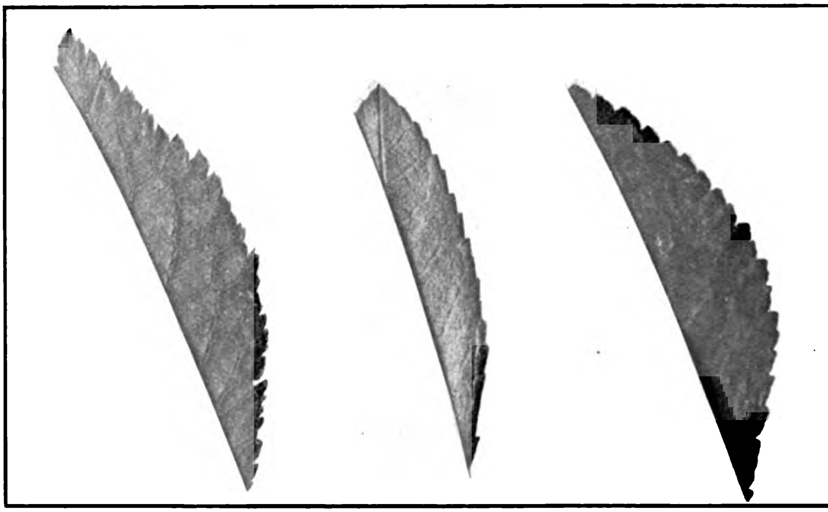
Where Montmorency was used as a male parent the sandcherry hybrids appear fairly evenly distributed among the different classes, there being not far from one-fourth of the population in each class.

Where Wyant was the male parent the Mendelian proportions were not so evident. The Wyant character dominated in a majority of cases. Only about 15 per cent of the plants were intermediates, and these favored the sandcherry in the form of the base of the leaf.

Tip of leaf.—The leaf of Montmorency is characterized by a broad limb with taper-pointed tip, as also is that of Wyant, but the sandcherry leaf is narrow with a rather obtuse tip. See figure 5 and figure 6. Following is the classification of the F_2 plants with respect to the leaf tip:

Group.	Sandcherry × Montmorency, F_2		Sandcherry × Wyant, F_2.	
	Number.	Per cent.	Number.	Per cent.
1	29	22.40	19	15.2
1a	22	17.05	19	15.2
2a	45	34.80	43	34.4
2	33	25 57	44	35.2
Total population..	129	.....	125	....

The sandcherry-Montmorency hybrids approximate the 25 per cent expected according to the monohybrid formula in the groups 1 and 2. The distribution in the intermediate groups 1a and 2a indicates the



Wyant. Sand Cherry. Montmorency.

Fig. 7. Types of Serrations.

The simple obtuse serration of the sandcherry as compared with the rather acute serrations of the Montmorency and Wyant.

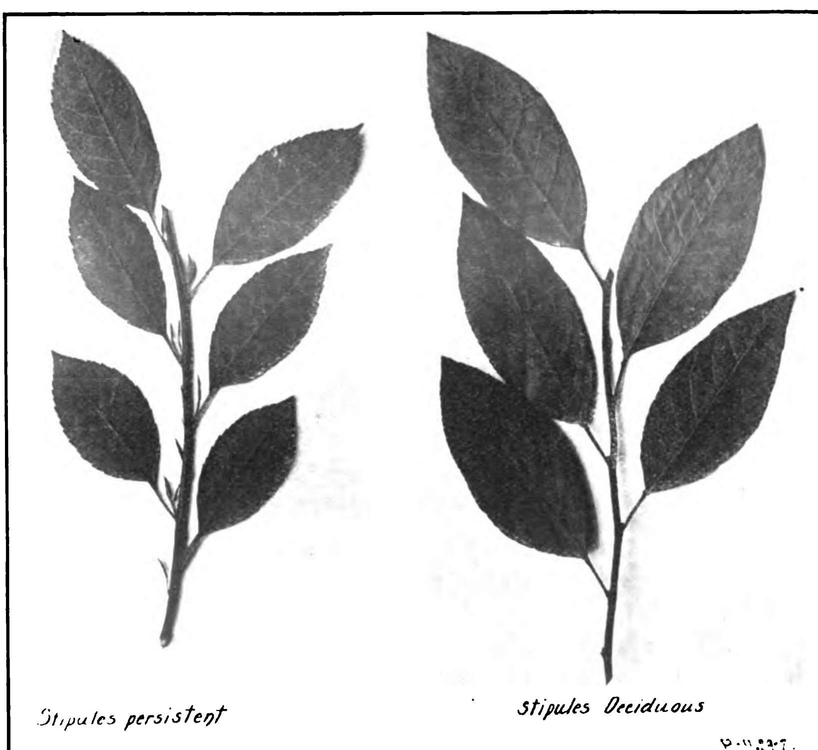


Fig. 8. Persistency and Deciduousness of Stipules of F_2 Hybrids of Sandcherry × Montmorency.

imperfect dominance of the Montmorency tip. The Wyant tip likewise appears imperfectly dominant, but the groups 1 and 2 do not in this case approximate the expected 25 per cent.

Serration.—The serration of the sandcherry is simple and obtuse, while that of Wyant is sharply acute and often double. See figure 7.

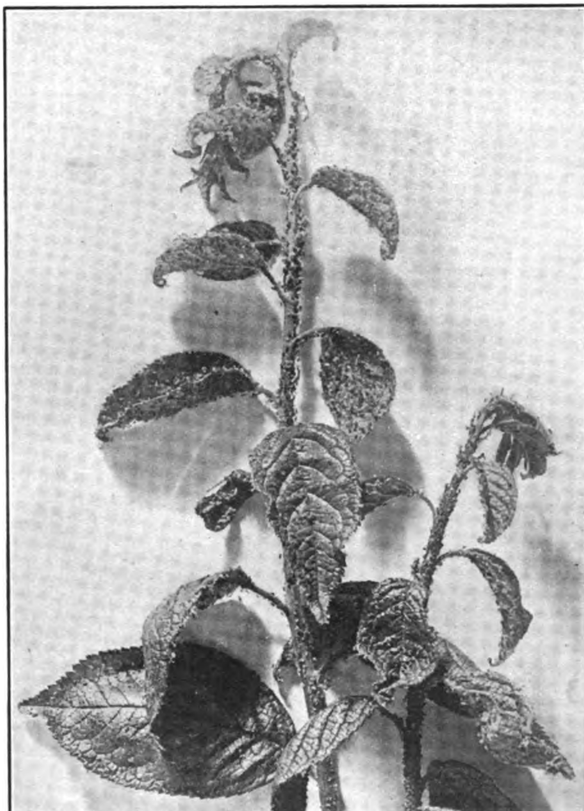


FIG. 9. WYANT BRANCH SHOWING SEVERE INFECTION WITH APHIS.

Following is the classification of the F_2 sandcherry-Wyant hybrids with respect to this character:

Group.	Number.	Per cent.
1	46	36.8+
1a	34	27.2
2a	12	9.6
2	33	26.0
Total population.................	125	....

It appears that the Wyant character is recessive and the sandcherry dominant or imperfectly dominant for the most part.

Number of serrations.—As a result of numerous measurements it was found that the number of serrations to the inch averaged 9.7 on

FIG. 10. SANDCHERRY BRANCH SHOWING TOTAL FREEDOM FROM APHIS ATTACK.

the sandcherry and 12.6 on Wyant. The classification follows. The results are inconclusive.

Group.	Number.	Per cent.
1	14	11.2
1a	29	23.2
2a	37	29.6
2	45	36.0
Total population................	125	....

Ratio of length to width.—In making this classification ten typical leaves each of sandcherry and plum were measured in inches and the ratio of the length to the width of each was ascertained.

The sandcherry has a long and comparatively narrow leaf. In this case the ratio went as high as 3.12″: 1.00″, and as low as 2.65″: 1.00″.

The Wyant plum has a long leaf, but it is also quite broad. In this case the ratio ran as high as 2.32″: 1.00″, and as low as 1.95″: 1.00″.

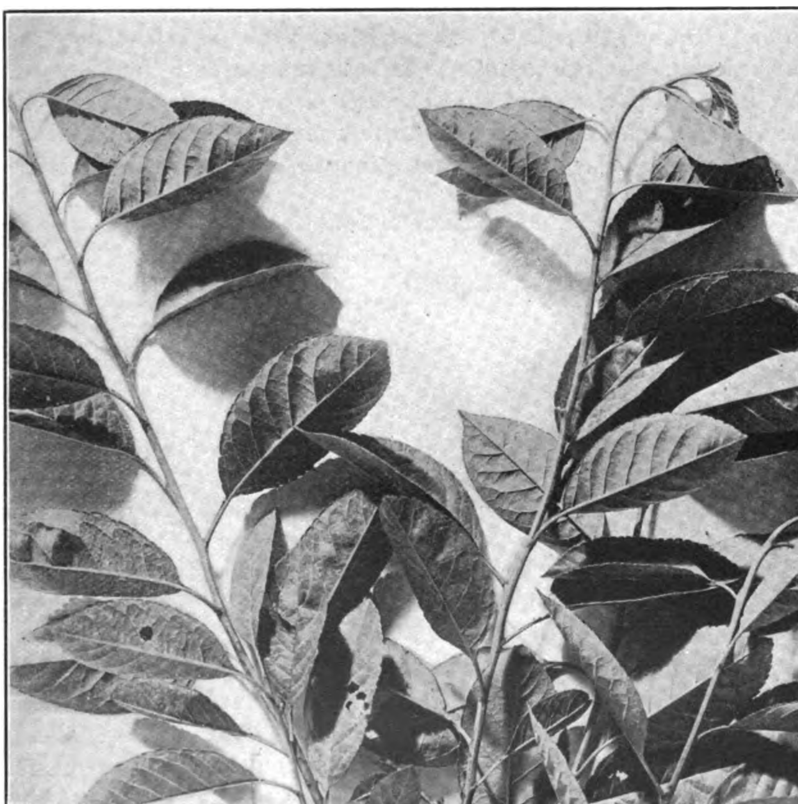


FIG. 11. HYBRIDS OF SANDCHERRY × WYANT SHOWING FREEDOM FROM APHIS ATTACK.

On the basis of these ratios the following grouping was worked out. Typical leaves from 123 of the hybrids were measured and the ratios determined. The result as given in the following table shows that the sandcherry takes the place of a Mendelian recessive in this character.

Group.	Number.	Per cent.	Ratio.
1	30	24.3	2.65" and above: 1.00"
1a	21	17.07	2.45" to 2.65": 1.00"
2a	14	11.3	2.32" to 2.45": 1.00"
2	58	47.1	2.32" and less: 1.00"
Total population.........	123	....	....

Stipules.—In the Montmorency cherry the stipules are early deciduous, while in the sandcherry they are persistent. In the F_2 hybrids the stipules on some plants are persistent while on others they are early deciduous. See figure 8. An examination of F_2 plants made late in the season showed the character of persistent stipules to be recessive. Following is the classification as made at that time. Possibly observations continued from spring to fall might discover intermediate forms.

Group.	Sandcherry × Montmorency, F_2.	
	Number.	Per cent.
1	96	74.4
1a	..	....
2a	..	....
2	33	25 6
Total population.................	129	....

Habit of tree.—These F_2 hybrid trees are standing about 8 inches apart in nursery rows on fertile black prairie soil. The conditions favor vigorous growth. Marked differences in habit of tree appear among the various individuals. Some are tall and thrifty and are now at least 9 feet high. Others are very dwarf, being not more than from 12 to 15 inches high. Cherry trees of the same nursery age are 6 feet or more in height, while the most vigorous sandcherries have reached a height of 3½ to 4 feet. The following classification of the F_2 plants is based on estimates by the eye, rather than on exact measurements.

Group.	Sandcherry × Montmorency, F_2.		Sandcherry × Wyant, F_2.	
	Number.	Per cent.	Number.	Per cent.
1	32	25.8+	30	24.0
1a	22	17.7+	15	12.0
2a	60	48.3	62	49.6
2	10	8.06	18	14.4
Total population..	124	....	125	....

In both sets of hybrids the sandcherry habit of growth appears to take the place of a Mendelian recessive, while the cherry and plum respectively show imperfect dominance.

Aphis resistance.—During the summer of 1910 aphis was very abundant on cherry and plum foliage at Ames. Adjacent to the rows of

FIG. 12. F_2 HYBRID OF SANDCHERRY × WYANT SHOWING APHIS INFESTATION.

F_2 plants of the sandcherry × Montmorency hybrids and separated from them by a distance of only 4 feet, stood a nursery row of 63 seedlings of the Bixby plum of about the same age as the hybrids. The Bixby seedlings were all badly infested with aphis. Among the adjacent F_2 hybrids mentioned some were attacked by the aphis while others were immune throughout the season. No aphis was found on the sandcherry. See figure 10.

Similar results were found with the hybrids of sandcherry × Wyant. See figures 10, 11, 12. Whether the immunity in these cases was due to physiological or to structural characters of the leaf has not been determined.

The following statement shows the classification of these hybrids with respect to immunity from aphis.

Group.	Sandcherry × Montmorency, F_2.		Sandcherry × Wyant, F_2	
	Number.	Per cent.	Number.	Per cent.
1	96	74.4	92	73.6
1a	..	.....	..	.....
2a	..	.....	..	.....
2	33	25.6	33	26.4
Total population .	129	.....	125	....

From this it appears that in both sets of hybrid plants the character of immunity from aphis is Mendelian. Susceptibility to aphis attacks is transmitted by both the Montmorency cherry and by the Wyant plum as a recessive character, being found in approximately 25 per cent of the F_2 population.

Correlation.—It was observed that in the F_2 hybrids of sandcherry × Montmorency all plants which were infested with aphis and had leaves with the Montmorency type of base also had the Montmorency type of color of foliage. However, the converse did not hold true.

With a single exception all of the F_2 hybrids of sandcherry × Wyant which were infested with the aphis and which had foliage with the Wyant type of color also had leaves with the Wyant type of base. The converse did not hold true. The leaf of the exceptional plant referred to had an intermediate form of base favoring the sandcherry.

The hybrid plants which were attacked by the aphis resembled in texture the Montmorency or Wyant respectively, according to their parentage, while those which were immune from the aphis resembled the sandcherry most closely in form, color and texture.

VARIATION STUDIES OF THE VENATION ANGLES AND LEAF DIMENSIONS IN VITIS[a]

M. J. DORSEY

St. Anthony Park, St. Paul, Minnesota

The grape is one of our oldest cultivated plants. Many of its characters have been carefully analyzed, especially by European workers, from the standpoint of taxonomy. These studies have been carried forward with special reference to *Vitis vinifera*, but since the American species have come into general use in Europe as stock for grafting, they have also received considerable attention. Considering the importance of the grape commercially, a study of any of its characters which may be of value to the breeder in its improvement is not considered out of place. It was from this standpoint that this work was begun.

A study of the variability of the vine characters of the species is important from the standpoint of the breeder in the investigation of crosses and hybrids. Considerable importance has been given to certain leaf characters by some workers, and it was desired in this work to investigate the variability of some of them with the view of determining their value from the standpoint of the breeder. It is intended to set forth the variation of certain leaf characters between individuals within the species, and variety as a basis for comparison.

The writer wishes to acknowledge his indebtedness to Dr. H. J. Webber for valuable suggestions throughout the work and to Dr. H. H. Love for assistance in the statistical treatment of the subject; to Prof. U. P. Hedrick, horticulturist at the New York State Experiment Station, for material collected from the station vineyards, and to Mr. F. E. Gladwin, of the same station, for assistance in obtaining material from the Chautauqua Experimental Vineyard.

The Leaf of Vitis.—The leaves of different species are very variable and in some are quite characteristic. They possess taxonomic characters which are alone sufficient in some species for identification. Among other characters size, shape, lobing, the petiolar sinus, and the under surface present interesting points for comparison. In the table below, compiled from different sources, these are compared in eleven different species.

[a] Paper No. 19 Department of Plant Breeding, Cornell University, Ithaca, N. Y. The major portion of the subject matter was presented in a thesis for the degree of Master of Science in Agriculture to the Graduate Faculty of Cornell University in 1910.

Other leaf characters could be included in a table of this nature, but these will suffice to show briefly specific differences. A careful study of any of these characters within the species or variety will show considerable variation.

Methods.—Considering the variability of leaf characters in *Vitis* it is believed that the statistical method of analysis is an accurate way to express these variations and their relations to each other. The formulæ for the coefficients in this paper may be found in the *Principles of Breeding* by Davenport. The classes as given in all of the tables are the middle points.

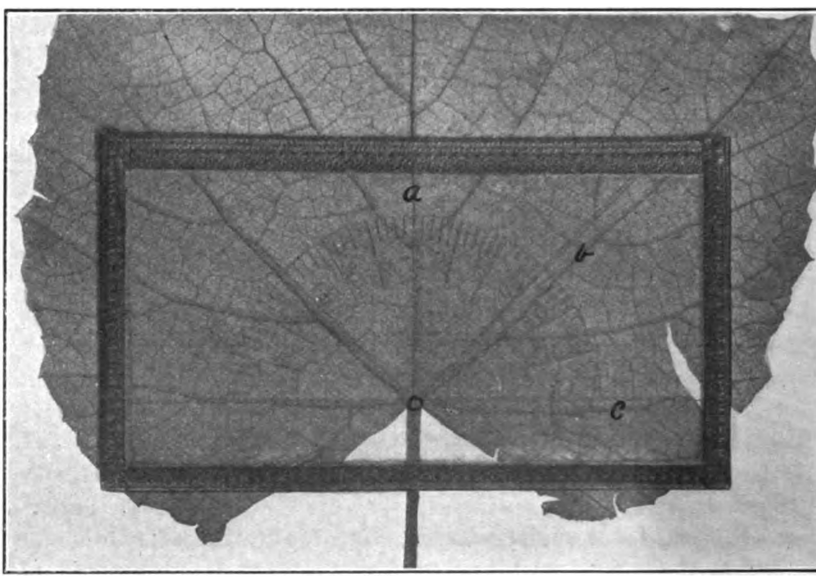


FIG. 1. METHOD OF MEASURING VENATION ANGLES.

Measurements of the leaf dimensions were taken in centimeters. The breadth was measured across the widest portion perpendicular to the midrib; the length, from the point of attachment of the petiole to the apex; while the petiole length was taken from the base of the blade to its attachment on the cane.

The angles studied were those formed by the midrib with the first and second large veins radiating from it, arising at the point of attachment of the petiole. The angle formed by the midrib and the first large vein is designated by a; the angle between the first and second large veins is designated by b. The angle ab then is $a + b$. It was

thought best to measure both angles from the midrib as a basis, in order that the relation between them might be compared. The method of measurement together with the transparent protractor used is shown in figure 1. The circumference is graduated into spaces differing by three degrees which are numbered, reading each way from a radius perpendicular to the base. The zero mark is placed on the midrib and readings taken in either direction. Angle *a* is *aob*, and angle *ab* is *aoc*.

Material.—The material used in this work was obtained from different sources. All of the leaves of *Vitis vulpina* were collected from vines growing near Geneva, N. Y.; those of *Vitis bicolor* were obtained from the same region, except two vines which were collected in central Ohio. For a number of species measured, herbarium specimens were used. The sex of each vine is indicated where it could be determined with certainty. In most cases all of the normal mature leaves were collected from each vine; in cases where all were not taken the selection was made at random. No attempt was made to select vines growing under uniform conditions, as to soil, altitude, etc.

Characters Studied.—The leaf characters which have been analyzed statistically in this paper may be divided into two classes: (1) A study of the variability and relationship of the leaf dimensions, and (2) a study of the angles of venation and their range of variability.

RESULTS OF OTHER INVESTIGATORS

Two articles have appeared recently in which studies of venation angles have been made, and used for very different purposes. Ravaz[2] used the venation angles and the ratio of vein lengths as taxonomic characters in variety and species descriptions, and Sacca,[3] an Italian worker, found a correlation between the size of the angle formed by the midrib and the outer large vein at the base of the leaf, and productivity.

Work of Ravaz.—Ravaz made extensive use of the venation angles and the ratio of vein lengths in variety descriptions in *Les Vignes Americaines.* In order to eliminate as far as possible the variation in these characters, he used the leaves borne on the canes from the 9th to the 12th node. He considered the characters of these to be quite constant. The method used in making the angular measurements

[b] Ravaz, L.: *Les Vignes Americaines, Porte-Greffes et Producteurs Directs, Characters Aptitudes*, Paris, 1902.

[c] Sacca, R. A.: *Lo Sviluppo del Perimetro Fogliare in Rapporto alla Produttivita delle Viti.* 12 pp., figs. 1-3. Piacenza, 1909.

is shown in figure 2, which is copied from his work. The angle alpha corresponds to angle *a* of the writer and angle beta to *ab*.

The general form of the leaf depends upon the venation, and is, according to Ravaz, determined by the relative length of the primary veins. For example, in a reniform-shaped leaf as that of *Vitis rupestris*

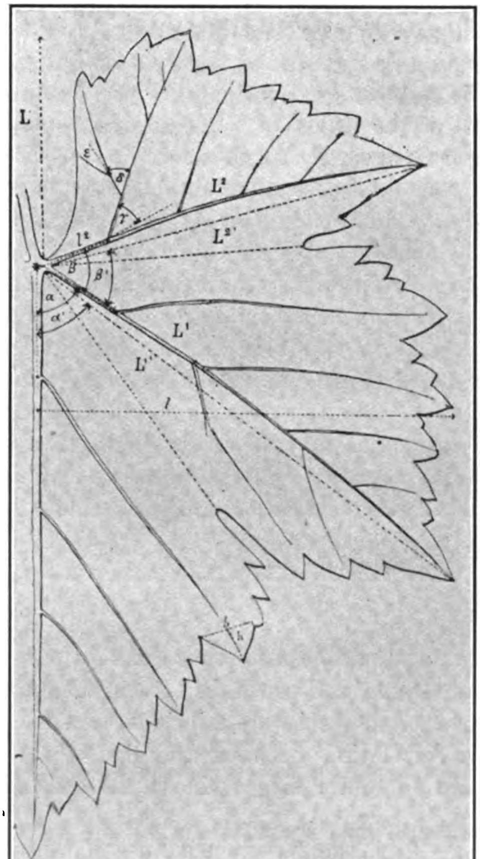


FIG. 2. DIAGRAM OF GRAPE LEAF ILLUSTRATING FORM OF VENATION.
(Copied from Ravaz.)

type, which is entire, he shows that the lateral veins are long in proportion to the midrib and that the angles alpha and beta are acute. By increasing the size of these angles the petiolar sinus becomes narrow and the base of the leaf becomes rounded off as in *Vitis bicolor*. Reducing the lateral veins in length, the leaf becomes cuneiform as in *Vitis vulpina*.

Ravaz treats the venation of the leaf in considerable detail, from the standpoint of its form. He regards the midrib as the most important vein, the two main lateral ones on either side deriving their direction from it. These veins constitute the main framework of the leaf and exist before the enlargement. All separate from the same point, which is called the petiolar point. Each one divides and subdivides into secondary, tertiary, quarternary nerves, etc. Ravaz regards the angles formed by the veins as constant for each variety, in the

TABLE 1.—*Leaf characters of vitis.*

Species.	Size.	Shape.	Number of lobes.	Petiolar sinus.	Under surface.
Vitis aestivalis.....	Large	Roundish	3 to 5 or 7	Narrow	Pubescent, rusty color
" berlandieri ...	Medium	Broadly cordate	Entire to 3 lobed.	U-shaped	Glabrous, dk. green.
" bicolor........	Large	Roundish cordate	3 to 5 often 7 or entire	Narrow	Glabrous, with bluish bloom.
" candicans.....	Small to medium	Broadly cordate	Entire or 3, 5, 7 lobed.	Broad	Densely pubescent, whitish.
" cordifolia.....	Small	Cordate pointed	Entire	Rather narrow	Glabrous or nearly so, green.
" doaniana.....	Medium	Cordate broad	Entire or shallowly 3 lobed.	U-shaped or narrow.	Pubescent or cottony whitish.
" labrusca......	Large	Broadly cordate or roundish	Entire, sometimes 3 lobed.	Broad	Densely pubescent bronze or dun colored.
" rotundifolia	Small	Roundish	Not lobed	Usually shallow and wide	Glabrous or thinly pubescent, greenish.
" rupestris......	Small	Wider than long	Entire	Very wide or truncate.	Glabrous, light green.
" vinifera.......	Large	Roundish	Usually 5, varying from entire to 7 lobed.	Variable narrow and overlapping.	Slight pubescence or hairy, whitish.
" vulpina.......	Medium to large	Roundish pointed	Entire, rarely lobed.	Broad, U-shaped.	Hairy, light green.

leaves, as mentioned from the 9th to the 12th node. The subdivisions of the lower lateral vein control the petiolar sinus and, like the others, are also regarded as constant for the variety. This author considers the angles formed by the veins as excellent taxonomic characters, and in a number of cases are sufficient to distinguish varieties.

In order to determine the variability of the angles in leaves collected as recorded by Ravaz, 52 Concord vines were selected growing under very uniform conditions as to soil and culture, in the Chau-

Table 2.—*Averages of angles from 9th to 12th node.*

Vine No.	Angle of Venation.							
	Left side of vine.[1]				Right side of vine.			
	Left side of leaf.[2]		Right side of leaf.		Left side of leaf.		Right side of leaf.	
	Angle *ab*	Angle *a*	Angle *a*	Angle *ab*	Angle *ab*	Angle *a*	Angle *a*	Angle *ab*
1	81.	38.2	38.2	81.7	96.	46.5	45.	89.7
2	98.2	57.	48.7	90.	91.2	50.2	43.5	90.7
3	83.	39.	42.	81.	96.7	51.	54.	100.7
4	91.	43.	47.	90.	93.	48.	46.	97.
5	89.2	43.5	43.5	85.5	97.5	48.	50.2	91.5
6	96.	48.7	49.5	97.5	86.2	45.7	47.2	90.
7	89.2	45.	45.7	89.2	93.	46.5	48.7	96.7
8	96.7	51.	45.7	93.	92.	48.	43.	92.
9	90.	45.	44.2	91.5	92.2	45.	48.	92.2
10	90.7	45.7	42.7	87.	88.5	48.	47.5	92.2
11	90.7	45.	51.	98.2	90.	45.7	49.2	95.2
12	89.2	45.7	44.2	86.	93.7	46.5	50.2	102.
13	91.5	50.5	48.	90.5	96.7	49.7	48.	96.
14	101.2	52.5	49.5	94.5	90.7	48.	46.5	87.
15	99.	50.2	47.2	91.5	95.2	48.7	53.2	103.5
16	....	....	....	....	91.5	47.5	49.5	90.7
17	93.7	50.2	48.	86.2	96.7	50.2	46.5	92.2
18	88.5	46.5	45.	85.5	89.2	45.	50.2	94.5
19	94.5	48.	45.	96.	86.2	44.2	45.7	87.7
20	90.7	47.2	45.	88.5	87.7	43.5	45.	88.5
21	99.	50.2	49.5	96.7	89.2	45.7	45.7	89.2
22	96.7	45.7	46.5	97.5	98.2	49.5	48.7	95.2
23	93.7	45.7	46.5	92.2	89.2	46.5	45.7	87.
24	93.	48.7	50.2	99.	89.2	43.5	45.	91.5
25	96.7	48.	51.7	101.2	96.	42.7	46.5	97.5
26	105.	51.7	51.7	99.	96.	48.7	48.7	93.7
27	....	....	....	....	96.	48.	49.7	90.7
28	97.5	49.5	49.5	95.2	97.5	51.7	52.5	93.7
29	90.7	52.	45.7	88.5	88.5	45.7	45.7	90.7
30	91.5	46.5	42.7	90.	91.5	46.5	50.2	98.2
31	87.	45.7	46.5	87.	90.	49.5	48.7	93.7
32	83.2	41.2	42.7	87.	89.2	46.5	50.2	96.
33	93.	49.5	56.2	105.	94.5	46.5	51.7	102.7
34	91.5	47.2	46.5	90.	90.7	48.	46.5	90.
35	84.	44.2	43.5	87.	85.5	41.	48.	95.2
36	90.	49.	47.2	91.5	91.5	45.7	49.5	93.
37	87.7	45.7	44.2	90.7	97.5	48.7	49.5	97.5
38	94.5	49.5	47.5	90.	93.	49.5	46.5	95.2
39	85.5	44.2	45.7	87.7	85.5	45.	48.	90.
40	89.2	47.5	47.5	89.2	95.2	46.5	45.7	92.2
41	88.5	47.5	43.5	90.7	94.5	45.7	45.	95.2
42	98.2	50.2	51.	103.7	94.5	48.	54.	100.5
43	94.2	47.2	46.5	91.	92.2	48.	47.2	89.
44	85.5	43.5	43.5	90.	85.2	46.5	38.2	78.
45	102.	51.	49.5	97.5	91.2	45.7	50.2	97.5
46	87.	45.	44.2	87.	88.5	47.5	44.2	85.5
47	90.7	45.7	43.5	86.2	86.2	43.5	46.5	90.
48	92.2	46.5	43.5	90.7	93.	48.	50.2	98.2
49	93.7	51.	51.	93.7	89.2	43.7	45.7	93.
50	101.2	49.5	48.7	96.7	87.	45.	45.	91.5
51	93.7	47.5	44.2	87.7	87.7	44.2	44.2	88.2
52	96.7	51.	48.7	97.5	99.7	51.5	50.2	96.7

[1] Left side of vine as one stands facing the row and passes down the row to the right.
[2] Measured from upper side of leaf.

tauqua Experimental Vineyards of the New York State Experiment Station. These vines were mature, in good health and vigor and trained according to the Kniffin system. The leaves from the 9th to the 12th node were taken from one of the larger canes (usually the upper) on each side of the vine. To check the results further, those from each side were kept separate and measurements were made of the angle formed by both the first and second large lateral veins with the midrib, on each side of the leaf. In the table below is recorded the averages of the angles *a* and *ab* for the four leaves from each cane, on either side of the vine. The angles also are given for each side of the leaf, considering the midrib as dividing the leaf into a right and left side, facing it from the upper surface.

TABLE 3.—*Frequencies for angle ab.*

	Class in degrees.																			Total.
	69	72	75	78	81	84	87	90	93	96	99	102	105	108	111	114	117	120	123	
Distribution of angle *ab* in Total leaves measured..	1	4	15	31	29	56	130	131	130	90	51	55	43	22	9	5	4	1	1	808
Distribution of averages (Table 2), angle *ab*......	....	....	....	1	3	11	31	60	36	39	12	8	3	....	....	....	....	....	....	204

TABLE 4.—*Frequencies for angle a.*

	Class in degrees.												Total.
	33	36	39	42	45	48	51	54	57	60	63	66	
Distribution of angle *a* in all leaves....	6	26	41	117	198	171	113	79	39	12	5	1	808
Distribution of the averages (Table 2), angle *a*..............................	....	....	4	21	76	63	35	3	2	....	....	....	204

In this table, the averages show a wide range of variation, either for the angles on each side of the leaf, or on leaves from each side of the vine. For angle *ab* the averages vary from 78 to 105 degrees, while the extremes for the average of angle *a* are 38.2 and 57. These averages show less variability than the measurements from which they were made; this is shown in the following tables.

The mode for angle *ab* falls on the class 90 in both arrays while in the table of arrays for angle *a* the modal class is 45 degrees in each case.

The angle *ab* for Concord is given at 110 degrees by Ravaz. This is somewhat higher than shown by measurements taken in this country; however, in the above table of frequencies for angle *ab* it will be seen

that nine angles have a value of 111 degrees, with eleven still higher. From the total measurements made, it will be seen that the averages of the angles from the leaves taken from 9th to the 12th node may fall anywhere between 78 and 105 degrees.

These measurements show that the angles of the leaves from the 9th to the 12th node are not constant for the variety Concord and that if the angle of venation is to be made use of as a taxonomic character, the mode or mean of a number of measurements is the more reliable index of the value of the angle.

Work of Sacca.—In his work on the development of the leaf perimeter in relation to yield in grapes, conducted in the botanical laboratory of the Royal Agricultural High School of Portici, Sacca finds productivity to be correlated with the size of the angle formed by the outer secondary vein with the midrib (angle *ab*). In discussing the stability of this angle under different environmental conditions, he considers the framework of the leaf as being quite constant and he considers that under favorable growing conditions the greater quantity of parenchyma produced results in a crumpled or wavy leaf rather than increasing the angle of venation to adjust itself to the greater amount of tissue. In order to investigate this point, Sacca selected 150 vines of Seibel No. 1 and divided them into three lots of 50 vines each. Two of these plots were given different manurial treatment while the third was used as a check. Examination of the veins showed that the angle remained constant in the three lots of vines. In the manured sections, however, Sacca notes that the leaves were in some cases almost fleshy and the parenchyma raised so that the veins appear sunken or the surface curved so as to render it undulating, yet these variations did not affect the direction of the veins.

Considering the angle formed by the midrib with the external lateral vein to be constant for each species and variety, and that they are not changed by cultural differences since they constitute the stable framework of the leaf, Sacca holds that vines whose leaf skeletons are different will, when subjected to the same treatment, always have a different productivity, and that this is correlated with yield.

The vineyard from which he obtained the material for this work was set in 1904, the vines being 1.75 meters apart in rows which were 1.1 meters wide. Six plants of each variety were selected, all of the same age, and all were pruned according to the same system, leaving an equal number of spurs, fruit and leaf buds. In October, 1905, the first fruit was harvested, the clusters were kept separated, weighed, and analyzed in the laboratory. The experiment extended through a

number of seasons and the data obtained in subsequent years agreed with that of 1905.

In the following tables, taken from the work of Sacca, a complete list of the varieties used in the experiment is given, grouped into

TABLE 5.—*Table of Type A, from Sacca.*

Name of variety.	Size of angle (angle *ab*).	Productivity.	Resa in must.	Sugar in must.	Acid in must.	Observations.
Seibel N. 29	129°36′	36.630	0.656	21.58	11.03	
Seibel N. 2003	127 28	39.208	0.717	18.01	9.25	
Couderc 82—12	123 22	34.091	0.633	18.95	8.39	
Calabrese	121 56	35.002	0.702	23.00	7.00	Undulating
Tuccarino	119 08	24.500	0.560	14.55	11.75	
Seibel N. 1	119 32	24.450	0.710	20.80	8.30	
Terras N. 20	119 14	21.847	0.650	21.17	7.58	
Couderc 4401	115 19	21.950	0.687	19.76	7.60	
Primestico	115 14	30.770	0.488	14.37	11.25	
Mourvedre × Rupes	110 36	20.000	0.610	14.10	7.10	
Couderc 85—113	110 24	20.070	0.592	18.95	8.30	Undulating
Morfuso	108 08	17.557	0.652	14.87	10.45	
Couderc 89—23	107 56	26.587	0.747	17.26	8.89	Undulating
Berlan. × Rupes 301B	105 00	23.750	0.560	15.37	10.80	
Iauffreau	102 42	14.925	0.566	22.13	6.82	
Cataratto	105 24	16.918	0.553	14.05	10.00	
Couderc 3907	100 02	15.300	0.775	22.90	8.62	
Seibel N. 2	100 51	24.525	0.698	21.63	7.00	Undulating.
Average	113°0′26″	*24.95	0.642	18.52	8.89	

* Correctly 24.8898.

TABLE 6.—*Table of Type B, from Sacca.*

Name of variety.	Size of angle.	Productivity.	Resa in must.	Sugar in must.	Acid in must.	Observations.
Berlan × Rup. 157″	95° 33′	10.827	0.554	14.85	10.25	
Id. 420β	95° 12′	9.552	0.560	14.925	8.26	
Id. 102$^{5\ ter}$	94° 10′	10.912	0.553	21.87	13.57	
Berlan × Rip. 34E	94°	10.605	0.483	14.52	10.60	
Ripar. × Rupes. 3309	93° 50′	8.231	0.500	15.61	9.25	
Ripar. × Berl. 420A	86° 22′	9.25	0.488	14.30	8.95	
Couderc 74^{17}	82° 54′	9.	0.500	16.50	8.00	
Pardes Lacoste	80° 54′	13.268	0.648	20.72	8.513	
Average	90° 21′ 52½″	10.205	0.540	16.68	9.67	

TABLE 7.—*Table of Type C, from Sacca.*

Name of variety.	Size of angle.	Productivity.	Resa in must.	Sugar in must.	Acid in must.	Observations.
Rupestris 2B	80° 6′	7.23	0.492	15.80	10.30	
Solonis × Riparia	74° 14′	7.25	0.600	13.37	9.5	
Rupestris du Lot	65° 12′	7.05	0.475	15.20	10.87	
34 E(?)	58° 46′	4.00	0.450	14.00	11.500	
Average	69° 34′ 30″	6.38	0.504	14.59	10.54	

three types, A, B and C, with respect to the size of the angle of venation. The averages of each type set forth the relation between the angle and productivity.

An examination of the size of the angle formed by the midrib and the outer lateral vein, in the different species, will be of interest in this connection. In the table below, the species are arranged according to the size of the angle *ab*, as determined by Ravaz and the writer. While the relative rank in this table does not correspond exactly in all species, yet distinct differences in the venation angles are evident. The values given by Ravaz for the angle *ab* are relatively higher, a result probably of differences in source and selection of material and of the method of making measurements.

TABLE 8.—*Values of angle ab in the different species.*

Species.	Original measurements.		Compiled from Ravaz.	
	Number of angles measured.	Average size of angle *ab*.	Number of varieties included in average.	Average size of angle *ab*.
Vitis vinifera	17	107.65°		
" aestivalis	109	102.39	4	102.00°
" bicolor	3023	99.15		
" lincecumii	34	98.15	7	114.14
" labrusca	5050	90.87	31	123.61
" berlandieri	35	90.69	34	112.85
" cordifolia	92	87.75	5	116.20
" rotundifolia	105	85.10		
" Arizonica	51	83.71	3	101.33
" vulpina	2721	81.15	43	97.30
" rupestris	135	80.12	21	90.48
" candicans	111	69.16		

While the data presented here are not sufficiently extensive to be conclusive as to the relative rank of the species and while further measurements may result in a somewhat different grouping, they are, nevertheless, suggestive and show very decided differences between the species in this character.

It may be well here to examine the angle in crosses between species, in which the size of the angle is different. The following table, in which the different crosses are arranged in order of the size of the angle, was compiled from Ravaz.

These data in general show that the larger angle is dominant over the smaller. When *Vitis rupestris* is crossed with *Vitis riparia* (*Vitis vulpina*) and *Vitis vinifera*, the larger angle occurs in the *Vitis vinifera* cross, 115.72 compared with 99.43. *Vitis aestivalis* when crossed with

Vitis labrusca and *Vitis riparia* throws the larger angle with *Vitis labrusca*, which has the larger angle. Other combinations will be evident to the reader. From this we may infer that the specific difference in the angle has its influence in crosses much in the same way as in the varieties, although further measurements will be necessary finally to establish this point.

TABLE 9.—*Dominance of larger angle in hybrids.*

Species in cross with size of angle as determined by Ravas.	Number of crosses in average.	Average size of angle *ab*.
Vitis labrusca, 123.61°× Vitis vinifera ?*	21	131.86°
" labrusca, 123.61°× " aestivalis 102.00°	10	118.60
" rupestris 90.48 × " vinifera ?	39	115.72
" riparia 97.30 × " aestivalis 102.00	3	110.00
" labrusca 123.61 × " riparia 97.30	17	107.59
" riparia 97.30 × " rupestris 90.48	7	99.43

*Angle *ab* in *Vitis vinifera* ranks highest as determined by the writer.

These data are presented here in order to point out the difference in the angle of venation between the species and the probable influence of this upon the correlation which Sacca finds between productivity and size of the venation angle. An inspection of the tables taken from Sacca shows a large proportion of *Vitis vinifera* varieties or crosses between species having relatively large angles in type A, with type B and C, made up almost entirely of hybrids between native American species. Measurements made by Ravaz in general agree with those of Sacca and show relatively large angles for the varieties of *Vitis vinifera*, and smaller ones for crosses and varieties where *Vitis vulpina* or *Vitis rupestris* occur. The illustrations in the paper by Sacca of leaves of the types A, B, and C conform quite closely in type A with the *Vitis vinifera* leaf, in B of *Vitis vulpina*, and in type C to that of *Vitis rupestris*, indicating further the probable influence of the difference in the species on the grouping as given by him.

VARIATION OF THE ANGLE OF VENATION

1. *Variation within the Variety.*—Sacca regards the angle of venation as a constant character for the variety or species. Measurements of the angle *ab* made by the writer show considerable variation in this character both within the variety and species. Out of ten vines of *Vitis bicolor*, the mean of the angle *ab* ranges from 87.61° to 109.80°(Table 14). Eleven vines of *Vitis vulpina* show for the same

angle a variation of the mean from 74.15° to 87.32 (Table 15). Random populations were selected from each vine. In Concord, a variety of *Vitis labrusca*, the extremes of angle *ab* differ by 9.6959° in 35 vines taken consecutively in the row. Sixty mature leaves were gathered at random from each vine of this variety growing in the plots of the Chautauqua Experimental Vineyards of the New York State Experiment Station. The angle *ab* was measured on each side of the midrib, making 120 angles per vine instead of 60. While representing only 60 leaves per vine, this method is more desirable from the statistical standpoint where small numbers are concerned.

The frequency distribution for a total of 4142 angles measured is as follows:

This table includes the total number of the angles *ab* measured on both sides of the midrib. Throwing the angles from each side of the midrib, which were recorded separately as they were measured, into a frequency distribution, we get the following arrays:

TABLE 10.—*Frequency distribution of angle ab in a population of 4142 individuals in Concord.*

	Class in degrees.																						Total.
	51	54	57	60	63	66	69	72	75	78	81	84	87	90	93	96	99	102	105	108	111	114	117	
Frequency.	1	..	2	5	9	35	39	63	146	319	335	373	612	720	571	386	191	143	109	38	30	8	7	4142

It is of interest to note that in both arrays the mode falls on the class 90 and that the distribution is quite similar in each case, which indicates that the venation of the grape leaf is symmetrical with respect to the midrib.

TABLE 11.—*Arrays for angle ab on each side of midrib, in Concord.*

	Class in degrees.																						Total.
	51	54	57	60	63	66	69	72	75	78	81	84	87	90	93	96	99	102	105	108	111	114	117	
Frequency for *ab* on left	1	..	1	2	6	15	17	29	83	163	185	181	282	385	292	204	88	65	48	9	9	3	3	2071
Frequency for *ab* on right....	..	..	1	3	3	20	22	34	63	156	150	192	330	335	279	182	103	78	61	29	21	5	4	2071
Total.....	1	..	2	5	9	35	39	63	146	319	335	373	612	720	571	386	191	143	109	38	30	8	7	4142

Considering now the mean for the angle *ab* of each Concord vine measured, we have again a rather wide range of variation within the variety, as shown in the following table, in which the vines are numbered consecutively as they came in the row:

TABLE 12.—*The mean of angle ab for 35 Concord vines.*

Vine No.	Mean.	Number of angles measured. (*ab*)	Vine No.	Mean.	Number of angles measured. (*ab*)
1	89.7250	120	19	85.8250	120
2	92.9000	120	20	90.2750	120
3	91.6250	120	21	84.4250	120
4	92.2250	120	22	86.3750	120
5	89.3250	120	23	91.6250	120
6	89.3500	120	24	90.0750	120
7	88.0500	120	25	86.5500	120
8	91.0250	120	26	84.0250	120
9	91.3500	120	27	88.2750	120
10	87.9500	120	28	86.2500	120
11	88.8250	120	29	87.8000	120
12	89.9250	120	30	89.2500	84
13	87.8750	120	31	85.2250	120
14	92.6250	120	32	88.2750	120
15	90.5500	120	33	83.2041	98
16	91.5000	120	34	85.8500	120
17	88.3000	120	35	88.3250	120
18	87.0750	120			

In these 35 vines the mean for angle *ab* varies from 92.9000 in vine No. 2 to 83.2041 in No. 33, a difference, as has been stated, of 9.6959°. No attempt was made to correlate yield with the size of the angle *ab* as did Sacca, the fruit being already harvested when the material was collected; but if the contention of Sacca holds true, we would expect to find the larger yield associated with the vines having the larger angle. The constants in this table show that the mean of the angle *ab* varies within the variety, as has been shown within the species, even when collected under conditions which would tend to eliminate variation. These results, together with those showing the differences between the species in the angle of venation, indicate that further work is necessary before the conclusions of Sacca are finally accepted as a working basis in breeding.

II. *Variation of the Venation Angle within the Species.*—Differences in the angle of venation have been emphasized in discussing the work of Sacca and Ravaz. Let us now examine this character within the species. Original measurements, taken as previously described, have been made to determine the range of variation of angles *a* and *ab*, and

also the correlation existing between them in a number of wild vines of *Vitis bicolor* and *Vitis vulpina*. These data are included in the tables below.

TABLE 13.—*Correlation between angle a and ab in Vitis bicolor and Vitis vulpina.*

Vitis bicolor.		Vitis vulpina.	
Vine No.	Correlation.	Vine No.	Correlation.
III	$r = 0.8892 \pm 0.0102$	XIX	$r = 0.9021 \pm 0.0056$
XI	$r = 0.8238 \pm 0.0149$	XX	$r = 0.7966 \pm 0.0285$
VIII	$r = 0.7625 \pm 0.0151$	XII♀	$r = 0.7721 \pm 0.0151$
II♂	$r = 0.7471 \pm 0.0199$	XVIII	$r = 0.7658 \pm 0.0192$
V	$r = 0.6879 \pm 0.0190$	XIV♀	$r = 0.7608 \pm 0.0227$
X	$r = 0.6611 \pm 0.0218$	XVI♂	$r = 0.7332 \pm 0.0154$
VI	$r = 0.6566 \pm 0.0204$	XXII	$r = 0.7310 \pm 0.0255$
IX♀	$r = 0.6435 \pm 0.0120$	XV♀	$r = 0.6490 \pm 0.0285$
VII♂	$r = 0.6302 \pm 0.0221$	XVII♀	$r = 0.6045 \pm 0.0297$
IV	$r = 0.6138 \pm 0.0248$	XXI	$r = 0.5933 \pm 0.0363$
		XIII♀	$r = 0.5901 \pm 0.0236$

In Table 13 is given the coefficient of correlation between angle *a* and *ab* for the vines of *Vitis vulpina* and *Vitis bicolor* which were measured. These constants show a close relation between the size of these angles, showing that as one increases the other also increases. There is a greater range of the value of *r* (0.5901 to 0.9021) in *Vitis vulpina* than in *Vitis bicolor*, where *r* varies from 0.6138 to 0.8892. The value for *r*, or the relation between the angles in the two species, is quite similar, though the average is higher in *Vitis vulpina*, being 0.7899 as compared with 0.7116 in *Vitis bicolor*. In these correlation

TABLE 14.—*Mean and standard deviation of angles a and ab in Vitis bicolor.*

Vine No.	Angle *a*.		Angle *ab*.	
	Mean.	Standard deviation.	Mean.	Standard deviation.
III	54.9219° ± 0.2841	5.8362 ± 0.2009	109.7969° ± 0.3943	8.0993 ± 0.2788
II♂	55.9420 ± 0.2476	5.4936 ± 0.1751	109.5134 ± 0.4080	9.0539 ± 0.2885
VIII	49.5776 ± 0.2142	5.9236 ± 0.1514	104.3448 ± 0.3542	9.7972 ± 0.2505
V	47.5874 ± 0.1826	5.0580 ± 0.1291	102.6791 ± 0.3099	8.5822 ± 0.2191
XI	52.1549 ± 0 2661	5.7572 ± 0.1881	100.3803 ± 0.4032	8.7248 ± 0.2851
IX♀	47.0893 ± 0.1992	5.8466 ± 0.1408	98.5332 ± 0.3168	9.3005 ± 0.2240
X	48.1184 ± 0.2121	5.4831 ± 0.1500	97.1150 ± 0.3155	8.1558 ± 0.2231
IV	44.9375 ± 0.1732	4.3585 ± 0.1225	95.1667 ± 0.2598	6.5378 ± 0.1837
VI	43.8770 ± 0.1577	4.5216 ± 0.1115	94.4599 ± 0.2864	8.2122 ± 0.2025
VII♂	41.1150 ± 0.1436	3.9190 ± 0.1015	87.6106 ± 0.2679	7.3140 ± 0.1895
Average.	48.5321	....	99.9600	....

tables angle *a* was used as the subject and *ab*, the relative. The total arrays from these correlation tables are set forth in Tables 17 to 20 inclusive.

TABLE 15.—*Mean and standard deviation of angles a and ab in Vitis vulpina.*

Vine No.	Angle *a*.		Angle *ab*.	
	Mean.	Standard deviation.	Mean.	Standard deviation.
XIX	41.8488° ± 0.1811	6.0578 ± 0.1280	87.3242° ± 0.2958	9.8927 ± 0.2091
XVII♂	40.5721 ± 0.1656	3.5416 ± 0.1171	84.9808 ± 0.2367	5.0602 ± 0.1673
XII♀	39.8585 ± 0.1799	4.8069 ± 0.1272	82.3477 ± 0.3019	8.0677 ± 0.2134
XIII♀	36.0173 ± 0.1327	3.6654 ± 0.0938	80.5331 ± 0.2220	6.1317 ± 0.1570
XVIII	38.9147 ± 0.1951	4.2014 ± 0.1379	80.1185 ± 0.3055	6.5790 ± 0.2160
XV♀	36.8503 ± 0.1855	3.7615 ± 0.1312	78.7059 ± 0.3369	6.8313 ± 0.2383
XIV♀	36.4808 ± 0.1981	3.6684 ± 0.1401	78.6731 ± 0.3353	6.2091 ± 0.2371
XVI♂	37.5567 ± 0.1301	3.8883 ± 0.0920	78.6502 ± 0.1965	5.8729 ± 0.1390
XX	37.5200 ± 0.4907	6.3000 ± 0.3470	77.3466 ± 0.6523	8.3754 ± 0.4613
XXI	36.1655 ± 0.2495	4.4536 ± 0.1764	76.3448 ± 0.3360	5.9993 ± 0.2376
XXII	34.8947 ± 0.2127	3.8885 ± 0.1504	74.1513 ± 0.3489	6.3771 ± 0.2467
Average.	37.8799	....	79.9251	....

In Tables 14 and 15 are given the mean and standard deviation of angles *a* and *ab* for both species. The mean of angle *a* is with one exception higher in *Vitis bicolor*, the lowest 41.1150°, being in vine VII, which is less than 41.8488°, in vine XIX, the highest value for the same angle in *Vitis vulpina*. The standard deviations for angle *a* are less variable in *Vitis bicolor*. The average for the mean of angle *a* is 48.5321° in *Vitis bicolor* and 37.8799° in *Vitis vulpina*. The mean and standard deviation for angle *ab* is shown in the same tables. The mean for *ab* is highest in *Vitis bicolor*, ranging from 87.6106° in vine VII to 109.7969° in vine III, as compared with the range of the values in *Vitis vulpina* of 74.1513° in vine XXII to 87.3242° in vine XIX. The mean for this angle does not overlap in the two species as in angle *a*. The average of angle *ab* is 99.9600° in *Vitis bicolor* and 73.1841° in *Vitis vulpina*. The standard deviation for angle *ab* again is more constant in *Vitis bicolor* as was the case with angle *a*. The vines are arranged in these two tables according to the highest value for the mean of angle *ab*. It is of interest to note that the highest values of angle *a* do not in all cases correspond with those of *ab*, which shows that the ratio between the size of these two angles is not constant.

The ratio of the mean of angle *a* divided by that of *ab* $\left(\frac{a}{ab}\right)$ is shown in Table 16. The vines are arranged from left to right in the same

order as in Tables 14 and 15. In three cases in *Vitis bicolor* angle *ab* is less than one-half as large as *a*; this does not occur in *Vitis vulpina*. The ratio $\frac{a}{ab}$ is slightly higher in *Vitis bicolor*, though different for each vine in both species. Angle *ab* is in all cases more than twice as large as angle *a* in *Vitis vulpina*.

The class frequency for the size of angles *a* and *ab* respectively, for each vine of *Vitis bicolor*, is presented in Tables 17 and 18. Tables 19 and 20 show the same thing for *Vitis vulpina*. The arrays in these tables are arrranged in descending order with respect to the size of the mean of angle *ab*, the same order being kept with corresponding arrays of angle *a*. The arrays were taken from the correlation tables,

TABLE 16.—*The ratio of angle a/ab in Vitis bicolor and Vitis vulpina.*

VITIS BICOLOR.

Ratio of $\frac{a}{ab}$	Vine number.									
	III	II♂	VIII	V	XI	IX♀	X	IV	VI	VII♂
	0.5002	0.5108	0.4751	0.4635	0.5196	0.4779	0.4955	0.4722	0.4645	0.4693

VITIS VULPINA.

Ratio of $\frac{a}{ab}$	Vine Number.										
	XIX	XVII♂	XII♀	XIII♀	XVIII	XV♀	XIV♀	XVI♂	XX	XXI	XXII
	0.4792	0.4774	0.4840	0.4472	0.4857	0.4682	0.4637	0.4775	0.4851	0.4737	0.4706

the constants of which are shown in Table 13. In the tables for both species, the arrays for angle *a*, of any vine number, are the subject, in which the array of any corresponding number for angle *ab* is relative. The continuous line passes through each population at the mean. (For the exact mean of these populations, see Tables 14 and 15.) The direction of these lines shows a close relation between the two angles, *a* and *ab*, in both species.

The arrays for the total number of angles measured in each species are given in Table 21, which shows the class frequency and extremes for the array of each angle. In both species the highest value for angle *a* overlaps the lowest value for angle *ab*. In *Vitis bicolor* both angles range higher; in this respect the two species show a decided difference.

TABLE 17.—*Class frequency of angle a, for total population of each vine of Vitis bicolor.*

Vine.	Size of angle, in degrees.															Totals.
	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	
III			1		2	13	23	28	30	33	39	18	4	1		192
II♂					3	7	17	39	34	42	51	19	10	2		224
VIII			1	14	34	57	87	58	45	22	17	9	2	1	1	348
V			5	15	47	90	77	70	25	4	12	3	1			349
XI				2	6	26	42	43	40	19	23	7	4		1	213
IX♀		2	4	36	50	121	82	42	11	6	36	2				392
X		4	6	13	17	79	74	65	16	13	14	2	1			304
IV		1	21	51	34	111	49	16	3		1	1				288
VI	1	6	12	74	69	123	52	28	6	1	1	1				374
VII♂	3	11	49	75	113	64	18	6								339
Total..	4	24	99	280	375	691	521	395	210	140	194	62	22	4	2	3023

TABLE 18.—*Class frequency of angle ab for the total population of each vine of Vitis bicolor.*

Vine.	Size of angle, in degrees.																							Total.
	69	72	75	78	81	84	87	90	93	96	99	102	105	108	111	114	117	120	123	126	129	132	135	
III							2	1	10	10	6	14	29	26	17	19	18	23	8	4	5			192
II♂					2			3	6	3	23	27	23	29	17	25	22	24	14	4	2			224
VIII				2	3	4	12	14	16	31	38	41	46	39	32	27	15	13	8	4	2	1		348
V					2	2	9	17	34	49	25	32	66	49	31	12	6	8	2	2	2		1	349
XI				2	1	4	8	20	16	33	32	21	27	19	14	3	6	3	2	1	1			213
IX♀			1	2	5	8	11	95	42	52	8	14	97	12	10	14	5	16						392
X			4	1	7	2	16	54	44	36	28	35	42	22	10			1		2				304
IV			2		1	2	29	60	58	47	31	16	28	11	1			2						288
VI		3	1	6	16	11	18	90	69	51	31	23	27	20	4				1		2		1	374
VII♂	3	6	13	21	35	39	63	76	40	20	11	5	3	1			2	1						339
Total...	3	9	21	34	72	72	168	430	335	332	233	228	388	228	136	100	74	91	35	17	14	1	2	3023

TABLE 19.—*Class frequency of angle a, for the total population of each vine of Vitis vulpina.*

Vine.	Size of angle, in degrees.														
	24	27	30	33	36	39	42	45	48	51	54	57	60	63	Totals.
XIX	1		13	42	78	90	53	146	39	27	9	3	8		509
XVII♂				11	26	65	64	33	9						208
XII♀			10	35	84	47	28	114	7						325
XIII♀		5	31	77	128	64	34	8							347
XVIII			4	28	49	63	29	34	3		1				211
XV♀			12	40	59	46	19	11							187
XIV♀			18	25	52	39	19	3							156
XVI♂			18	70	123	105	62	22	5	1					406
XX			14	15	12	12	8	9	3	1				1	75
XXI		1	15	42	47	16	6	17	1						145
XXII			29	46	51	14	3	8	1						152
Totals.	1	6	164	431	709	561	325	405	68	29	10	3	8	1	2721

TABLE 20.—*Class frequency of angle ab, for total population of each vine of Vitis vulpina.*

Vine.	Size of angle, in degrees.																						
	51	54	57	60	63	66	69	72	75	78	81	84	87	90	93	96	99	102	105	108	111	114	Totals.
XIX					4	11	9	10	39	57	51	17	39	112	50	41	17	16	23	13			509
XVII♂									6	28	36	44	35	41	12	5	1						208
XII♀					3	10	1	9	62	63	44	8	22	66	19	12	1		5				325
XIII♀				1	1	5	9	14	51	87	70	31	25	43	9	1							347
XVIII					1	6	5	10	40	44	40	18	17	24	5						1		211
XV♀					2	12	8	16	27	45	28	15	12	19	3								187
XIV♀				1	3	5	4	12	25	36	33	21	7	6	2		1						156
XVI♂					2	8	21	36	78	107	63	37	23	20	8	3							406
XX					2	6	7	9	13	14	9	2	5	6		1						1	75
XXI				1	2	9	5	24	39	28	20	6	5	4	1	1							145
XXII	1			3	3	21	13	15	41	34	13	2	1	4	1								152
Total.	1			6	23	93	82	155	421	543	407	201	191	345	110	64	20	16	28	13	1	1	2721

The results obtained from these measurements may be briefly summarized as follows: The angle of venation is not a constant character either within the variety or species; in either, however, the mean and frequency distribution show decided differences, which in some species

TABLE 21.—*Arrays for the total number of angles measured in Vitis vulpina and Vitis bicolor.*

Class.	Vitis vulpina.		Vitis bicolor.	
	Angle *a*.	Angle *ab*.	Angle *a*.	Angle *ab*.
24	1	....	....	....
27	6	....	....	....
30	164	....	4	....
33	431	....	24	....
36	709	....	90	....
39	561	....	280	....
42	325	....	375	....
45	405	....	691	....
48	68	....	521	....
51	29	1	395	....
54	10	....	210	....
57	3	....	140	....
60	8	6	194	....
63	1	23	62	....
66	....	93	22	....
69	....	82	4	3
72	....	155	2	9
75	....	421	....	21
78	....	543	....	34
81	....	407	....	72
84	....	201	....	72
87	....	191	....	168
90	....	345	....	430
93	....	110	....	335
96	....	64	....	332
99	....	20	....	233
102	....	16	....	228
105	....	28	....	388
108	....	13	....	228
111	....	1	....	136
114	....	1	....	100
117	....	....	....	74
120	....	....	....	91
123	....	....	....	35
126	....	....	....	17
129	....	....	....	14
132	....	....	....	1
135	....	....	....	2
Totals.	2721	2721	3023	3023

are quite characteristic and may be used taxonomically. In Concord the averages of the angle *ab* in leaves taken from the 9th to the 12th node fluctuate about a mode approximating 90 degrees. In *Vitis bicolor* the arrays for angles *a* and *ab*, although overlapping have

decidedly different modes and extremes than in *Vitis vulpina*. The correlation between angle a and ab is approximately the same in both species; the standard deviation is higher in both species in angle ab, while the mean for both angles is greater in *Vitis bicolor*. The ratio of $\frac{a}{ab}$ varies slightly in the different vines in each species but is quite constant in both.

THE LEAF DIMENSIONS AND THEIR RELATIONS

The two species, *Vitis vulpina* and *Vitis bicolor*, were made the basis of this study, the object being to determine how constant the

TABLE 22.—*Mean and standard deviation of length of petiole, length of leaf and breadth of leaf in Vitis bicolor.*

Vine.		Length of petiole.	Length of leaf.	Breadth of leaf.	Size of population.
I		....	$M = 11.2797 \pm 0.1164$	$M = 14.1049 \pm 0.1401$	143
		....	$\sigma = 2.0634 \pm 0.0823$	$\sigma = 2.4855 \pm 0.0991$	
III		....	$M = 11.8509 \pm 0.1601$	$M = 14.6228 \pm 0.1851$	114
		....	$\sigma = 2.5348 \pm 0.1132$	$\sigma = 2.9302 \pm 0.1309$	
IV		$M = 8.8161 \pm 0.1360$	$M = 10.9226 \pm 0.1257$	$M = 12.3710 \pm 0.1288$	310
		$\sigma = 3.5490 \pm 0.0961$	$\sigma = 3.2805 \pm 0.0889$	$\sigma = 3.3622 \pm 0.0911$	
VI		$M = 10.8193 \pm 0.1027$	$M = 14.0693 \pm 0.1304$	$M = 16.0592 \pm 0.1514$	332
		$\sigma = 2.7756 \pm 0.0727$	$\sigma = 3.5216 \pm 0.0922$	$\sigma = 4.0909 \pm 0.1071$	
VII♂		$M = 8.7032 \pm 0.1520$	$M = 12.0645 \pm 0.1513$	$M = 12.4645 \pm 0.1392$	155
		$\sigma = 2.8059 \pm 0.1075$	$\sigma = 2.7933 \pm 0.1070$	$\sigma = 2.5685 \pm 0.0984$	
VIII		$M = 7.4589 \pm 0.1576$	$M = 8.5266 \pm 0.1269$	$M = 10.3091 \pm 0.1402$	207
		$\sigma = 3.3618 \pm 0.1114$	$\sigma = 2.7077 \pm 0.0898$	$\sigma = 2.9897 \pm 0.0992$	
IX♀		$M = 7.3630 \pm 0.0975$	$M = 11.8123 \pm 0.1283$	$M = 13.3679 \pm 0.1170$	405
		$\sigma = 2.9083 \pm 0.0689$	$\sigma = 3.8270 \pm 0.0970$	$\sigma = 3.4919 \pm 0.0828$	
X		$M = 6.9772 \pm 0.0802$	$M = 10.0211 \pm 0.0804$	$M = 12.1634 \pm 0.0913$	569
		$\sigma = 2.8355 \pm 0.0567$	$\sigma = 2.8420 \pm 0.0568$	$\sigma = 3.2293 \pm 0.0646$	
XI		$M = 4.8304 \pm 0.1330$	$M = 9.0179 \pm 0.1901$	$M = 11.0714 \pm 0.2188$	112
		$\sigma = 2.0869 \pm 0.0940$	$\sigma = 2.9820 \pm 0.1344$	$\sigma = 3.4323 \pm 0.1547$	
Average....		7.8526	11.0623	12.9445	

leaf dimensions and their relations were in individual vines within the species. These relations were also used as a means of comparing the leaf of one species with that of the other. The mean and standard deviation have been determined for the length of petiole, and length and breadth of leaf, in populations representing a number of vines of each species. These constants are set forth in the different tables below.

TABLE 23.—*Mean and standard deviation of length of petiole, length of leaf, and breadth of leaf of Vitis vulpina.*

Vine.		Length of petiole.	Length of leaf.	Breadth of leaf.	Size of population.
XII ♀	M =	4.1130 ± 0.5989	7.7209 ± 0.6687	8.5580 ± 0.7752	301
	σ =	1.5404 ± 0.4235	1.7201 ± 0.4729	1.9941 ± 0.5482	
XIII ♀	M =	5.2240 ± 0.0835	9.5847 ± 0.1278	9.6995 ± 0.1237	183
	σ =	1.6752 ± 0.0591	2.5633 ± 0.0904	2.4810 ± 0.0875	
XIV ♀	M =	4.7718 ± 0.1590	9.7753 ± 0.2539	10.3483 ± 0.2838	89
	σ =	2.2244 ± 0.1125	3.5517 ± 0.1796	3.9693 ± 0.2007	
XVI ♂	M =	4.7500 ± 0.6901	8.5200 ± 0.8511	9.3533 ± 0.9981	300
	σ =	1.7722 ± 0.4880	2.1855 ± 0.6018	2.5629 ± 0.7056	
XVII ♂	M =	6.5810 ± 0.1178	11.6571 ± 0.1814	12.2000 ± 0.1939	105
	σ =	1.7903 ± 0.0833	2.7562 ± 0.1283	2.9452 ± 0.1371	
XV ♀	M =	4.5426 ± 0.0939	10.0213 ± 0.1327	9.9468 ± 0.1269	94
	σ =	1.3500 ± 0.0664	1.9073 ± 0.0938	1.8239 ± 0.0897	
XVIII	M =	7.2099 ± 0.1703	11.4366 ± 0.1692	13.1737 ± 0.1949	213
	σ =	3.6856 ± 0.1204	3.6607 ± 0.1196	4.2163 ± 0.1378	
XIX	M =	5.9332 ± 0.0852	11.0039 ± 0.0918	11.9116 ± 0.1051	509
	σ =	2.8491 ± 0.0602	3.0721 ± 0.0649	3.5150 ± 0.0743	
XX	M =	7.2286 ± 0.2740	11.2286 ± 0.3158	11.8000 ± 0.3643	70
	σ =	3.3982 ± 0.1937	3.9176 ± 0.2233	4.5186 ± 0.2576	
XXI	M =	6.1769 ± 0.1931	11.8912 ± 0.2206	12.0816 ± 0.2475	147
	σ =	3.4714 ± 0.1366	3.9661 ± 0.1560	4.4485 ± 0.1750	
XXII	M =	5.9882 ± 0.1494	11.1059 ± 0.1791	11.1059 ± 0.1977	170
	σ =	2.8881 ± 0.1056	3.4626 ± 0.1267	3.8226 ± 0.1447	
Average....		5.6837	10.3587	10.9253	

TABLE 24.—*Ratio of length of petiole to length and breadth of leaf and leaf breadth to leaf length in Vitis bicolor.*

Vine.	Petiole length. / Leaf length.	Petiole length. / Leaf breadth.	Leaf breadth. / Leaf length.
VIII	0.8752	0.7235	1.2096
IV	0.8071	0.7146	1.1295
VI	0.7690	0.6737	1.1414
VII ♂	0.7214	0.6982	1.0331
X	0.6963	0.5736	1.2137
IX ♀	0.6233	0.5508	1.1317
XI	0.5356	0.4363	1.2277
I	....	....	1.2505
III	....	....	1.2339
Average............	0.7183	0.6244	1.1746

The mean and standard deviation of the leaf dimensions for *Vitis bicolor* are given in Table 22; coefficients for the same characters for *Vitis vulpina* are presented in Table 23. In neither species does the standard deviation follow the mean for any of the dimensions. It is not largest, either, in the vines having the highest mean for any character. The average of the mean for each dimension shows a different relation of the leaf parts in the two species. The petiole is longest in *Vitis bicolor* while the leaf length in *Vitis vulpina* is shorter in relation to its width.

In Tables 24 and 25 the vines are arranged in order according to the highest value for their mean length of petiole divided by their

TABLE 25.—*Ratio of length of petiole to length of leaf and breadth of leaf, and leaf breadth to leaf length in Vitis vulpina.*

Vine.	Length of petiole. / Leaf length.	Length of petiole. / Leaf breadth.	Leaf breadth. / Leaf length.
XX	0.6438	0.6126	1.0509
XVIII	0.6304	0.5473	1.1519
XVII♂	0.5645	0.5394	1.0466
XVI♂	0.5575	0.5078	1.0978
XIII♀	0.5450	0.5386	1.0120
XXII	0.5392	0.5392	1.0000
XIX	0.5392	0.4981	1.0825
XII♀	0.5327	0.4806	1.1852
XXI	0.5195	0.5113	1.0160
XIV♀	0.4881	0.4611	1.0586
XV♀	0.4533	0.4667	0.9926
Average............	0.5467	0.5184	1.0631

mean length of leaf. In general, though not in every case, the ratio of length of petiole over leaf breadth corresponds with that for petiole length over leaf length. In both species the ratio of leaf breadth divided by leaf length is independent of the ratio for the other leaf dimensions. These tables express in another way the relation between the leaf dimensions. In *Vitis bicolor* petiole length divided by leaf length gives the higher average for this ratio, showing the greater length of petiole in proportion to leaf length in this species. The average ratio for breadth of leaf over length is higher in *Vitis bicolor*, showing greater leaf breadth in this species in proportion to leaf length.

The extreme value (measured in centimeters) of each leaf dimension, found in a total of 3166 leaves in *Vitis bicolor* and 2894 in *Vitis vulpina* is given below:

Dimensions.	Vitis bicolor.	Vitis vulpina.
	Centimeters.	*Centimeters.*
Length of petiole	1 to 20	1 to 19
Length of leaf	2 to 25	4 to 23
Breadth of leaf	3 to 29	3 to 24

The extremes are greater in *Vitis bicolor.*

The average of the mean for each dimension in both species when thrown into a table results as follows:

Dimension.	Vitis bicolor.	Vitis vulpina.
	Centimeters.	*Centimeters.*
Length of petiole	7.8526	5.6837
Length of leaf	11.0623	10.3587
Breadth of leaf	12.9445	10.9253

The average leaf of *Vitis bicolor* is larger.

The average ratio, showing the relation of the dimensions in each species is given below:

Ratio of—	Vitis bicolor.	Vitis vulpina.
	Centimeters.	*Centimeters.*
$\frac{\text{Petiole length}}{\text{Leaf breadth}}$	0.6244	0.5184
$\frac{\text{Petiole length}}{\text{Leaf length}}$	0.7183	0.5467
$\frac{\text{Leaf breadth}}{\text{Leaf length}}$	1.1746	1.0631

The average for each ratio is higher in *Vitis bicolor.*

These measurements show that the leaf of *Vitis bicolor* is larger than in *Vitis vulpina,* the greater extremes for the mean of each dimension being in the former. The petiole is longer in proportion to the length of leaf in *Vitis bicolor,* while the leaf is shorter in relation to its width in *Vitis vulpina.*

SUMMARY

The grape is one of our oldest cultivated plants. The leaf of *Vitis* is quite variable in the different species and has, in some, taxonomic characters which alone are sufficient for identification. Studies have been made of the angle of venation for purposes of taxonomy and also as correlated with other characters. In problems of this nature

statistical methods should be used, and large populations dealt with to secure accurate values for venation angles, either within the variety or species. The variation occurring in the angle of venation renders this character less valuable for taxonomic purposes where only slight differences occur between species or varieties. Further study is needed to establish finally the correlation which Sacca believes to exist between the angle formed by the midrib and the second large lateral vein (angle *ab*) and productivity, owing to the influence which the differences between the species have upon the grouping as given by him. The limited data available indicate that the larger angle (angle *ab*) is dominant in crosses.

Within the species and the variety different individuals have distinct frequency distributions for the venation angles. In *Vitis bicolor* both angle *a* and *ab* have a larger mean than in *Vitis vulpina*, although in both species the correlation between these two angles is high, showing a close relation in different leaves. Angle *ab* in both species is approximately twice as large, though this ratio is not quite constant. Of the species studied by the writer *Vitis vinifera* has the largest angle *ab*, and *Vitis candicans* the smallest.

Studies of the leaf dimensions of *Vitis bicolor* and *Vitis vulpina* show that the leaf of *Vitis bicolor* is larger, has a longer petiole in proportion to length of leaf, and a shorter leaf in proportion to its width.

ANNUAL REPORT OF COMMITTEE ON BREEDING NUT AND FOREST TREES

GEO. B. SUDWORTH, *Chairman*

Washington, D. C.

In previous reports the aims and scope of this committee's work have been fully outlined, and the problems which were pressing for solution were also pointed out. From now on the annual reports of this committee as a whole will necessarily consist of an account of the general progress made in tree breeding, supplemented by specific contributions along various lines on which more or less conclusive results have been obtained.

The actual work of tree breeding, including the improvement of nut trees, is now carried on mainly through two agencies: First, through expert commercial tree breeders, and, second, through the carefully planned and systematically organized investigations at the several forest experiment stations under the direction of the

United States Forest Service. As a result and as indicative of activity in this field on the part of private investigators we are able to offer a contribution by Prof. G. L. Clothier on the "Possibilities of Breeding the Smaller Nuts," and one by Prof. W. L. Bray on "The Possibilities of Breeding Certain Texas Species of Trees for Planting in Warmer Semiarid Regions."

In presenting these papers the committee does not, of course, pretend to exhaust what has been accomplished by private investigators in the field of breeding and improving nut trees. A very great deal of valuable work has been done in this direction, as professional papers and experiment station records clearly show. Unfortunately it was impossible for the committee this year to give a complete summary of what has been accomplished in that particular field by investigators who are not members of the American Breeders Association. It is hoped, however, that in the near future a summary of what has been done can be presented in the annual reports of the committee. Thus the committee will be able to acquaint the Association with the results obtained in the breeding and improvement of nut trees, both in this country and abroad.

As a result of experiments in forest-tree breeding by the Forest Service, we have an important contribution from the standpoint of the forester, by G. A. Pearson, on "The Influence of the Age and Condition of Trees upon Seed Production in Western Yellow Pine." The tree-breeding experiments conducted by the Forest Service are carried on at the two forest experiment stations, one at Flagstaff, Ariz., the Coconino Station, and one near Manitou, Colo., the Fremont Experiment Station.

During the last year work at the Coconino Forest Experiment Station was confined to the study of the effect of the age and health of mother trees upon the seedling offspring, the detailed results of which are incorporated in Mr. Pearson's article. At the Fremont Forest Experiment Station there was begun a series of experiments dealing with various problems in the breeding of forest trees. The following is a full account of these various experiments.

BREEDING OF FOREST TREES

In the practical work of planting forest trees it frequently becomes necessary to choose between two available supplies of seed, both possibly from distant sources. To what extent the source as well as the germinative quality of the seed may influence the success of the operation, and to what extent stock from distant points will prove

adaptable to the local conditions, is always a doubtful question. If it can be proven that climatic varieties within the species will readily adapt themselves to new conditions, the now difficult problem of seed collecting will have been greatly simplified. If, however, trees grown from seed from a distant source prove susceptible to climatic factors to which their ancestors were not accustomed, then the work of seed collecting must be more fully systematized. To determine these points experiments were instituted with two species, western yellow pine and Douglas fir.

The first specific problem was to determine whether seed from the northern and southern limits of western yellow pine produce stock of different hardiness or rapidity of growth from that obtained from intermediate stations. For this experiment there were used one pound of western yellow pine seed from Boise, Idaho, a point within the northern limit of this pine's range, and one pound of western yellow pine seed from near Flagstaff, Ariz., a point within the southern limit of range, and one pound of western yellow pine seed from the vicinity of Pikes Peak, Colo., an intermediate point in the range of this yellow pine. Three plots of ground, each 40 by 40 feet, were selected near the upper vertical limit of the yellow pine growth and on a comparatively warm, southern slope. Similarly three plots of ground were taken at the lower vertical limits of yellow pine growth. The soil and other conditions on each set of plots were as nearly alike as possible.

Results.—Seed from the intermediate stations germinated best. Seed from the southern limit of growth produced larger seedlings than did seed from intermediate stations, but smaller than the plants from seed collected at the northern limit of growth. In other words, the largest seedlings came from the northern seed. Whether such seedlings will prove hardy outside of the northern habitat of the parent trees will be determined within the next few years.

The second problem attacked was to determine the possibility of growing the Pacific form of Douglas fir in the Rocky Mountains in preference to the Rocky Mountain form of this species, and to determine whether seed of the two forms will produce in this region stock differing essentially in the matter of growth and hardiness, or whether the discouraging experience of continental foresters with the Pacific Coast form of Douglas fir will be repeated here, thus prohibiting the use of the more rapid-growing form of this species in the Rocky Mountains.

It should possibly be explained here that in rapidity of growth and in commercial excellence of its wood the Pacific Coast form of Douglas

fir far exceeds the Rocky Mountain form of this species. It is desirable, therefore, to propagate the Pacific Coast tree wherever possible outside its natural habitat.

For this experiment one pound of Douglas fir seed collected in Oregon, and one pound of Douglas fir seed from Colorado were used. This seed was planted on three different sets of plots, the conditions in each pair of plots varying from conditions in any other pair.

Results of the first season's experiment show that the Rocky Mountain seed germinated best. Seedlings from Pacific Coast seed were larger and made greater stem growth than did those from Rocky Mountain seed. However, the Pacific Coast seedlings were not hardened off at the time of the first severe frost, as were the Colorado seedlings. This experiment needs to be continued for a number of years yet in order to solve the problem in hand.

INTRODUCTION OF EXOTICS

As pointed out in last year's report of this committee, one very important means of improving our timber forests is by the introduction of exotic species which are suited to the soil and climate, when for one or another reason such species are preferable to native species.

The term "exotic" as used here is applied to any tree that can be planted outside of its present natural range. The term is, therefore, not restricted to trees imported from another continent. In this arbitrary sense, the lodgepole pine is an exotic at the Fremont Experiment Station in Colorado, because the tree does not grow there naturally. Likewise the Rocky Mountain white pine is exotic to the forests of Colorado, as are also any of the eastern hardwoods or conifers to the entire West.

It seems quite possible that among the many species growing, for example, outside of Colorado there should be a few which will prove equal or superior to the three or four principal species growing there. Colorado is entirely lacking in commercially useful hardwoods, aside from the few cottonwoods and willows which grow along the streams, and the chaparral oaks. There is great need there of a valuable hardwood, and apparently there are many situations in Colorado where the soil is as good as would be demanded by any hardwood timber tree.

The shortness of the growing season at altitudes where moisture is sufficient to permit tree growth is the greatest impediment to the introduction of exotic trees, but this should not be an unsurmountable

obstacle, if trees from northern latitudes are chosen. In the introduction of exotics it is felt that wide latitude should be given the experiments even though in appearance the species chosen are not particularly promising.

The introduction of exotics at the Fremont Experiment Station, Colo., was confined to lodgepole pine, eastern white pine, Austrian pine, Scotch pine, eastern sugar maple, red oak, pignut hickory (*Hicoria villosa*). Both seed and forest grown seedlings were employed in this introductory work.

Results.—With the exception of Austrian pine, all these trees have done moderately well during the past season.

EXTENDING THE IMMEDIATE NATURAL RANGE OF FOREST TREES

An experiment closely related to the introduction of exotics was the attempt to extend the immediate natural vertical range of several timber tree species at the Fremont Experiment Station, Colo.

Thus an attempt was made to extend the vertical range of western yellow pine downward into the dryer zone, now chiefly occupied by chaparral oaks and by piñon pine and juniper, and into which the yellow pine does not go naturally. It has been frequently noted that the chaparral-oak-piñon-juniper types are lacking and that in such places the yellow pine extends down to the edge of the plains. Whether the presence of piñon pine, juniper, and chaparral oaks is due to accident or to soil conditions which can not be overcome is the important question to be decided by this experiment.

A similar attempt was made to extend the immediate vertical range of Douglas fir into the higher zone of Engelmann spruce.

Results.—While the results so far of extending yellow pine downward into the drier zone were not encouraging, the extension of Douglas fir upward into the higher zone of Engelmann spruce is encouraging. The growth of Douglas fir seedlings and the germination of seed were much better than within its normal vertical range.

These experiments, while well organized and well under way, will naturally require many years yet in which to obtain conclusive results. The improving of forest trees by direct breeding or by the introduction of new species is extremely slow work, because in the tree the cycle of life, from seed to maturity, requires many years.

Aside from the experiments just described for the Colorado Experiment Station, the Forest Service has successfully planted in southern California several thousand seedlings of cork oak (*Quercus suber*), the

tree which furnishes the world's supply of cork, and which, in so far as soil and climate go, can be successfully grown in this country. In addition to this planting of cork oak seedlings in California, the Forest Service has also sown a considerable quantity of cork oak acorns in Florida.

INTRODUCTION OF MARITIME PINE

Another of the Forest Service's introductions of exotic trees which promises a great deal for the forest wealth of the Southern States is that of the maritime pine (*Pinus maritima*). This pine has been very extensively planted in southern France, where the forests produced are the chief sources of French naval stores. Several thousand seedlings of this pine were planted last year in the Florida National Forest, and this plantation shows that the species is well adapted to the soil and climate of Florida. During the coming spring the Forest Service proposes to plant about 1000 pounds of maritime pine seed in the same forest.

The already apparent adaptation of this species to certain sections of our southern country, sections where useful native trees can be grown only very slowly, adds great interest to the outcome of this particular experiment.

A contribution of great importance in the improvement of forest trees was made at the last quadrennial meeting of the International Association of Forest Experiment Stations held at Brussels. At this meeting the results of testing the influence of the source of seed of Scotch pine on the stock produced, carried on by the different European stations, members of the Association, were fully discussed. Each station planted Scotch pine seed collected in different parts of Europe where this pine is cultivated, with careful notes on the character and condition of the parent trees. Thorough observations were recorded regarding the growth and form of the seedlings raised from these different lots of seed. It is hoped that the detailed results of this important experiment may form a part of this report when it is published.

Such, in brief, is the progress made along certain lines in improving nut and timber forests.

In this connection the committee wishes to emphasize again, as it did in former reports, that with respect to timber trees the only practical way of immediately improving their quality is by a judicious selection of the source of seed and by introducing new species into localities in which they will prove superior to native stock.

BREEDING EXPERIMENTS WITH SHEEP

T. R. Arkell

Durham, New Hampshire

The sheep breeding investigations at New Hampshire Experiment Station were commenced in the fall of 1908.

During the early winter of 1907–8 an arrangement was entered into with the Station for Experimental Evolution, at Cold Spring Harbor, N. Y., a department of the Carnegie Institution of Washington, by which that department agreed to coöperate with the New Hampshire Agricultural Experiment Station in the investigations of heredity in sheep. In accordance with that agreement Dr. C. B. Davenport, director of the department of the Carnegie Institution of Washington, has acted in an advisory capacity in planning the matings, in selecting the characteristics to be studied, in devising methods of recording the data, and in interpreting the results.

Five distinct breeds were included in the experiment, namely, Dorset, Hampshire, Shropshire, Southdown, and Rambouillet. Besides these, the flock contained many grade ewes which we have called New Hampshire native. These native ewes are simply the ordinary grade stock (found, I must admit, all too prevalently in New Hampshire) that for generation after generation have been bred in a desultory fashion and represent a heterogeneous mixture of many of the pure bred classes of sheep. They were chosen in the experiment largely to prove to the practical sheep breeder that it does not follow that what in a Mendelian sense is a pure character can exist only in the so-called purebred animals.

Reciprocal crosses of the Dorset and Southdown were made; also of the Dorset, Hampshire, Shropshire, and Southdown upon the Rambouillet. Rams of the foregoing breeds were also used upon New Hampshire native ewes. Many purebred animals were mated *inter se* and the inheritance of separate characteristics noted. We hope by so doing to be able to show to breeders that in the improvement of the breeds of sheep they can make advantageous use of Mendel's law and that the law operates just as clearly in the purebred types as when distinctly opposite characters are crossed.

In 1909 a mating system similar to that of the previous year was pursued. So far we have gotten altogether 100 F_1 individuals, 49 of which we were able to use for mating *inter se* last fall, to obtain the F_2 generation. Consequently, this spring we shall have our first F_2 offspring.

Several Leicester yearling ewes were added to the flock in 1910. These were mated with a Rambouillet ram. We anticipate most interesting data from this cross, especially in regard to wool characteristics, for since the Leicester possesses one of the coarsest of fleeces and the Rambouillet the finest, this combination should afford a most patent clew to the manner in which wool characters behave in heredity. Moreover, we were fortunate enough last year, through the kindness of Dr. Alexander Graham Bell and Dr. C. B. Davenport, to obtain a multinippled ram, possessing seven apparent nipples. He has been bred upon 40 ordinary two-nippled ewes. The advantage of raising a class of sheep with more than two active mammæ which means incidentally an increased milk production, is obvious to all shepherds, since at the present time ewes that can provide sufficient milk for the proper maintenance of two lambs are in number exceedingly limited.

Twenty-six characteristics have been distinguished, and records of these are kept for each sheep. Diagrammatic drawings are made to indicate particular features, where a verbal description cannot adequately explain relative differences. For example, distribution of wool on head, ears, and legs is described in this manner. A special chart has been prepared for this purpose on which all the characteristics for each individual are associated and shown together. Color of pigment of skin and wool is indicated—as to position on the body, by a diagram, and as to extent, by a numerical percentage grade. Accurate measurements are taken of the circumference at base and length of horns if present, the result being represented in a ratio of length to circumference. In fact, no measurement is taken of any part of the anatomy without comparing it in ratio with some other, as it is the only means of being able to recognize, between animals, relative differences of many features.

Hair color has involved a very great amount of detailed study. There are two colors; namely, black and white. The white is possibly a "gray" or dominant white, which, however, cannot be accurately ascertained until the F_2 generation is examined. The black pigment exists in the different breeds in varying degrees of intensity. For instance, in Southdown it is greatly diluted giving a light gray face, while in the Hampshire and Suffolk it is most intense giving a dark brown or black face. The F_1 heterozygotes produced from a cross between sheep possessing respectively dark and white hair color usually present a mosaic appearance.

The inheritance of horns, so far as the F_1 generation is concerned, from which we alone can judge, seems peculiar, although in harmony with Prof. T. B. Wood's sheep breeding experiments (October, 1909, issue of the *Journal of Agricultural Science*). When a horned sheep is crossed upon a hornless—it matters not which sex bears the horns all the male F_1 offspring are horned, while all the female F_1 offspring are hornless or virtually so. In no case are the horns of the F_1 rams so strong or large as those of the horned parent, although in every instance they were much greater than what are commonly called scurs. Only the F_1 ewes from Merino crosses developed any appearance of horns, and these must all be classed as scurs, as they were slight and loose and the circumference exceeded the length. The foregoing evidence shows that the inheritance of horns in sheep is apparently closely connected with sex. It is evident, however, that the horned condition is dominant; its absence, or the polled condition, recessive; but that in females something essential to the somatic development of horn is missing, or it may be possible that production of horn in the female is retarded and at times completely checked by the presence of an inhibiting factor which the male does not possess.

From a study of the F_1 offspring, distribution of wool, as applied especially to the face, ears, and legs, seems to be inherited in a most simple fashion. When a sheep heavily wooled upon poll and face is crossed with one not wooled, the F_1 displays wooling on poll and face but in less degree than the more heavily wooled parent. This applies in a similar manner to distribution of wool on ears and legs. Accordingly, this conclusion may be drawn, namely, the more extended or greater distribution of wool dominates over the less extended or sparser covering.

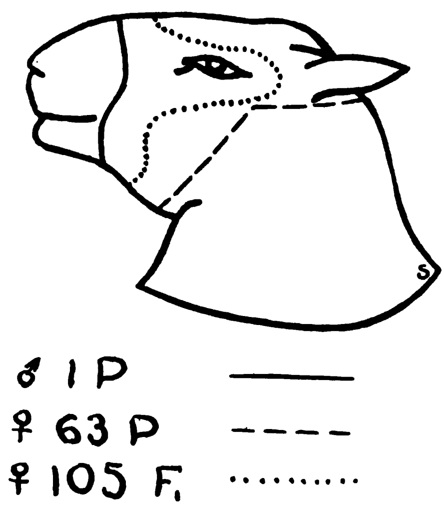
This feature is clearly illustrated in the diagram on the opposite page.

Data gathered from the F_1 generation tend to indicate that skin folding or wrinkling, which is a conspicuous character of the Merino type of sheep, is dominant over the non-folded or smooth skin of the medium and long-wooled breeds. A Merino crossed upon non-wrinkled sheep always produced offspring exhibiting skin folds, although in no case were the wrinkles so heavy or so many as possessed by the Merino parent.

It is not necessary to elaborate here on the inheritance of wool color. Our results correspond in every detail to those already worked out in this respect. Investigations have proved pretty clearly that the white wool is dominant over the black. This explains the frequent

appearance, especially in the Down breeds, of so-called black lambs and of small patches of black wool over the body. Pure black-wooled sheep will produce only black-wooled lambs, whereas white-wooled sheep, owing to the imperfect dominance of the white wool, are liable to bring forth offspring showing traces of black wool. Homozygous white wool is hard to distinguish and can be determined only by actual breeding tests.

Little more than a mere description of the methods followed in wool testing can be given at this time, as a sufficient number of records have not as yet been taken to permit the prediction of results. It is necessary first that the component characteristics making up the entire



Diagrammatic drawing showing the inheritance of wool covering on head: Wool covering of F_1 offspring is midway between that of both parents.

wool fiber be separated and their action in heredity distinguished before a true idea anent wool inheritance can be formed. Seven characters have been discerned, namely, length, crimp, tensile strength, elasticity, diameter, weight, and yolk content. The length, crimp, tensile strength, and elasticity of each separate fiber is obtained in one operation by means of a special machine built for that purpose. One thousand fibers taken from the fleece of every sheep, in, as nearly as can be ascertained, the same positions on the body, are used for making these determinations. The average diameter is obtained in the usual manner by examination under a microscope fitted with a micrometer eyepiece. Percentage of yolk in a fleece is determined

by the ordinary wool scouring method reduced to laboratory conveniences. Only a small sample, 25 grams, taken from the shoulder, is used.

Body measurements are mostly made by means of large calipers specially constructed for the purpose. These measurements are taken twice a year and regulated so as to have the ages of the sheep correspond in every instance. The system followed in making measurements and correlating the different parts in terms of a ratio can best be set forth in the following reproduction of part of the record blank used in the experiment for the original tabulation and description of characters:

NOSE.			NECK.			TRUNK.				FORE LEG.	
Sagittal lgh. to Horn Ridge.	Transverse diam. Skull at Poll.	Ratio TD / SL	Length: Horn Rdg. to 1st Thor. Vert.	Cir. Mid. between Horn Ridge and 1st Thor. Vert.	Ratio L / C	Length: 1st Thor. Vert. to Tail Head.	Dorsal Ventral dia. behind Fore Legs.	Tran. diam. behind Fore Legs.	Ratio TD / DVD	Length.	Ratio Leg L / Trunk L

HIND LEG.		LEG BONES.											
Length.	Ratio Leg L / Trunk L	Fore Ulna	Fore Knee to Foot	Ratio Ulna / K to F	Hind Tibia	Hind Knee to Foot	Ratio Tibia / K to F	Width of Loin.	Length of Croup: Apex of Ilium to Tail Head.	Ratio Loin / Croup	Hind Leg: Circum. as high as possible.	Ratio Tibia / Cir. H. Leg

Section of record chart, showing the system of taking and recording measurements.

The foregoing really represents only a brief review of the methods of prosecuting the sheep breeding experiment By next year, however, we hope to have enough individuals of the F_2 generation to enable us to report authoritatively on the manner of inheritance of many of the principal, and, from a commercial standpoint, most important characters in sheep.

FECUNDITY IN SWINE

Q. I. Simpson

Palmer, Illinois

There is, perhaps, no direct knowledge of what factors lead to the production of big broods in swine, so this paper must be largely composed of surmise and theory. A brief knowledge of the process of animal production; of the sperm, ovaries, and the ripening of the eggs; of the requirements by these of a spermatozoön to start embryonic growth and the like will furnish some subject matter for this discourse. Your writer's living having been gained since boyhood in the production of swine, you will pardon him, if much of this discussion is of personal experience.

I am convinced from experience, and from theory that selection is the great factor in producing fecundity. We have introduced some sows into our herds that threw small broods; the daughters of these, many times, also threw small broods. The wild breed of the German Schwarzwald has an average of six teats, and produces about four pigs per brood; there are domestic strains, breeds, and families having an average of thirteen teats which produce about eleven pigs per brood. Sheep possess two teats and produce an average of one and one-half young. If we accept Darwinism, it is a matter of degree in kinship between the wild sow, the ewe, and the sow of the barnyard; then, in this sense, the specific fecundity is heritable.

A young Tamworth sow was served by a wild Schwarzwald boar, and produced nine pigs; the daughters of this union, at their first farrowing produced, respectively, four, four, and six pigs (one of the four-producers had been served by her littermate). The original pure Tamworth sow in this experiment was herself from a twelve-pig brood. A sow in the second genesis, of the six-pig brood, was served by a pure Tamworth male and produced a twelve-pig brood at her first farrowing. I will not burden you with details but will simply state that we produced many subsequent hybrids, leading towards Tamworth and Yorkshire, and the preponderance of these wild hybrids, and some sows yet bearing a bit of the impotent wild blood were very prolific. The Tamworth × Wild sow, that had first farrowed the six pigs was at maturity served by a pure imported Schwarzwald boar, and produced seven pigs. The pure Tamworth sow, initiating the experiment, had fourteen teats; her hybrid daughters possessed respectively nine, nine, and ten. We are not sure, if there is any correlation in number of teats to fecundity; but know that

when fecundity is elevated the number of teats must also increase, or some unlucky fellows will "get left."

We have made some observation of prolific mothers that lead us to believe that daughters from such prolific sows, and daughters from these sows' sons, are themselves prolific; so much do we believe in this, that we do not use a boar or sow in our economic herd that is not from a big brood, and from a matured sow that has herself been tested in this line. I know men that are quite particular to save brood-sows only from big-broods, but will take a herd-boar from any source, without an investigation of his inherent fecundity. My own experiments with the wild hybrids would alone convince me of the folly of this practice. We spread before us the tabulated pedigree of the Trotting horse, the Thoroughbred, or the Jersey-cow; we estimate the percentage of cherished lineage equally through the male and female lines, and rightly, for the hybrid experimenter and the cytologist tell us that the heredity-potential is equal in both sexes. We ourselves have made many reciprocal-sex crosses, testing this, before we began Mendelian experiments. If the male can transmit milking-quality, trotting-action, or running-speed from his dam, then it seems he should hand down the fecundity degree, also, from his mother.

So earnestly do people around the Maine Experiment Farm believe in the egg-laying heredity of the Plymouth Rocks there, that they steal the young chicks to obtain the stock. Sows lay eggs, also; they fall into the womb, rather than the nest. Let us widen our conception of Darwinism a bit, and reason on the hen's fecundity, for which there are perhaps more reliable data than for swine.

There is an article by Director Wood of the Orono Station, on their illustrious egg family of Rocks, in Volume I of the A. B. A. It is known by poultrymen that hens lay very well without being mated with any cock; now we believe that one of the Orono hens would perhaps lay as many eggs, mated with a cock of a thirty-egg Langshan, as from one of the two-hundred-fifty-egg Rocks;—and they would most likely hatch; then would not a prolific sow, served by a boar of low-producing tribe, produce big broods? most likely, yes: but no doubt he would at the same time lower very much the fecundity of the daughters. We must not imply that any male can sire big-broods from prolific sows, for the question of egg-fertilization is at issue; there is the factor of polarity (kinship of sperm to ovum) as observation seems to show. Individual sows have produced through a series of years, small broods to males of kinship,

and have subsequently farrowed large broods, when stinted to a male of another breed.

Borrowing again from Darwin we have this example: Flowers have many and varied mechanisms for the prevention of self-fertilization, and for the enticement of cross-breeding. Many flowers contain abundant pollen, but there is the provision to prevent self-fertilization, of difference in time of ripening of pollen grain and ovule; or a mechanical bar against its own pollen reaching the receptacle. The gaudy color or attractive perfume is its method of bringing the impregnating insect to it with his cargo of foreign pollen from a distant plant. . May I be allowed to further surmise:

Segregating experiments are showing us that there are distinct, individual, reproducible, unchanging, units in the living cells of plant and animal; these are of smaller division than the half nucleus of either male or female, for the hybridizing shows that there are several of these units;—proven by the non-correlation of these units, all of the units from one parent not being found commonly on one of the brood, but usually on different members of the brood. Only rarely are all of the units of one parent found on any one individual in mass.

As we stated: inheritance shows that there is equal heredity value furnished by the male and female. Students of the cells, and of their subdivisions, the chromosomes, tell us that the male and female nuclear mass, that unites in fertilization to start the embryo, contains but half the normal number of chromosomes as do the normal body cells. If these then are the real units, and not the cells, then let us ask ourselves if these may not be the portion of the living organism that requires sexual rejuvenation, to maintain and entail normal and active life. Surely not the sap in plants, nor the lymph in animals that require sexuality. For with the latter, medical usage of lymph in immunizing has shown that an ounce of this from the blood of a horse does not make the human patient "horsey," but a single sperm of a thousandth grain weight can make the half of the inheritance; it could hardly be in the membrane of the cells, for this is lost in the fertilization process; so must it surely be some independent, living, reproducible enzymes, ferments, or catalysers inside the cells, that convert the common sap and common lymph into a red rose, yellow corn, or black walnut; or a white hog, black man or gray rat.

With a crude understanding of the cell's mechanism and its growth and reproduction—we may form some theory of the "why"

for sex, which accounts for blossom arrangement; and the cause of low-fertility and weak cell-growth in inbreeding. Let us represent the fused germ cell (or any cell) with the letter O; in growth it spreads longitudinally becoming finally from greater length constricted in the middle like a double O, thus: O–O. A good illustration of the lengthening and reproduction of cells may be imagined with a soft-shell egg by tying a string around the middle, constricting it to the form of two eggs. This is a good analogy of the reproduction of plant and animal cells. If we cast aside the "vital principle" and restrict the process to chemical and physical phenomena, then we alight on the "electro-chemical" theory, which to myself appears very plausible; and that can explain many of the "*whys*" in *life* and *sex*.

Now it seems that the bacteria-shaped rods, named chromosomes, in the cells, are the catalytic agents; these have the metabolic power to convert the sap in plants, and the lymph in animals that has filtered into the building cell through the cell-walls, from the fine capillaries of the vessels and arteries, into stems, roots, and seeds in plants; and into epithelia, bone, pigment, fat, hoof, horn, and hair in animal.

At the starting of the embryo, at the fusion of half-nucleus of sperm and egg, the half-colonies of chromosomes in each of these half-cells, were of different chemistry, somewhat, and of different magnetic potential; were positive and negative; hence, were drawn together not by ordination, or design, but by simple magnetic attraction. They remain in this magnetic stage during sufficient time to catalyse the lymph-substance to more than cell-size proportion, when they then individualy each reproduce themselves by single fisson, making two from one; and these each two being of same birth and chemistry, are identical in magnetic potential; hence repel each other to the farthest points in the longitudinal cell; thereby establishing two new points of radia in place of one, and thus building two cells from one in the process. This seems to be nature's plan, from the yeast cell to the cells of the highest flowering plants; and from protozoa to man; she has found no way of continuing life in organism without sooner or later introducing the *sexual rejuvenation* of the *Chromosomes.* When the two sets are so closely akin as to be chemically identical, it seems there can be no magnetic attraction to bring the male and female chromosome groups into union. Old age must be something like the running-out of magnetic potential; and the final outline and maturity of a plant or animal may be

governed by the dying-out, or cyclic termination of these bacterial-acting chromosomes.

Satisfied as to the point of required unlikeness, I will say that the *number* of spermatozoa must have something to do with the relative number of young in the brood; it is known that when young males inoculate sows the broods are usually quite small; also this may occur when old boars have been overworked.

I have made microsopic observation of the seminal fluid from males of various ages; and also examined sperm from the globus-major; and section from the globus-minor; the smaller, globus-minor, at the top-end of the larger gland, contains the spermatozoa undiluted; they are here of a richly creamy mass. and do not yet include the viscid liquid of the seminal fluid; this colloid is not added until the copulative act, and is secreted from the penal-canal. Sections from the larger gland show the spermatozoa in all stages of development; they seem to be nourished in growth through their tails from the larger nurse cells of the testis gland.

We deduce that the cause of small broods, by immature young males, is the lack of a sufficient number of spermatozoa; just as the unfilled corn ear growing isolated in the garden is supposed to have received insufficient pollen grains. The sperms are not endowed with design, nor with neural understanding, but are driven hither and whither by their automatic wriggling tails, into all the cracks, crevices and tubes of the female generative apparatus. But relatively few, perhaps ascend the fallopian tubes to find the eggs; just as but relatively few pollen grains alight on the capillary silks of the corn ear (a million times more fall between the corn hills and are wasted). Kindly accept what you can of the foregoing, which leads to the subject of nutrition, as effective in the supply of sperm and germ.

Our first experience was empirical; but later deductions have been made from more technical knowledge. For many years we had practised the "warming-up" of sows just before service, by supplying them with highly nitrogenous foods; they seemed to exhibit greater sexual desire under this treatment; our results have confirmed this. Chemists have said that egg and sperm are both rich in nitrogenous substance; the stimulated production of hen's eggs out of season was confirmatory; extra-fecundity seems to require a protein diet at the prefertilization period for the maximum production of ripe ova in the sow; abundant protein feed for the males makes the greatest in amount of sperm, and we have strong

proof of this; we can rapidly develop the visible size of testes on young males; and the quantity of sperm may be plainly observed in the enlargement of the globus-minor, storing them; it is in external view at the top-end of the testis gland.

In our groups of young boars being held for sale and shipment, proteids are only sparingly given; a week's ration of 20 per cent oil-cake meal puts the bunch into homosexual vulgarity. A Poland-China was easily brought to full vigor by a change from corn to oats; a nine-year-old Jersey bull would respond to oats and oil-cake meal; and a successful groom gave wheaten-flour to stallions in heavy service.

In conclusion I will say: I believe that we may *breed* fecundity; and increase it decidedly by proper nutrition. It may be gained, perhaps, in proportion to the desires of the pig breeder. If his aims are for show, quality, or fastidious-points, then fecundity in his herd will be at the minimum.

ANALYTICAL HYBRIDIZING

Q. I. AND J. P. SIMPSON

Palmer, Illinois

This is not greatly unlike the general processes in all the lines of man's research. The chemist knows his reactions; the enthnologist detects in the ceremonial, tribal relations; the linguist notes from the byword of the impulsive talker his former habitat; and the cosmogonist with spectroscope identifies the earth's mother.

In the ontogenetic and phylogenetic transmission of cells there are carried along by determiners or heredity vehicles certain marks of its phylea; these may lie hidden or stand visible in the individual; and it is for the invisible tribal indices that we simulate the chemist with analytical hybridization.

The visible indices may be lost through either natural or domestic selection; but the invisibles are carried along by panmixia, or free and promiscuous inter-crossing, like the harmless and neuter rudimentaries.

The distinctive visualities of color in our Mendelian experiments are so absorbing that it has directed our observation to the phenomena of pigment-localization and to color-pattern as a breed-index.

As you may know, all the young of wild *Sus scrofa* have on their bodies longitudinal black stripes on a field of pale straw-color; but

after the first moult (around four months' age) these stripes are oblit-erated by a full deposit of pigment in the hairs of the entire body; as if, after we had made a beautiful design with a striped stencil-plate, we spoil the work with a solid coat of darker paint.

The red Tamworth, a pedigreed breed named from a locality in Staffordshire, but whose origin is known through the old Irish pig to trace to the wild Scrofa, only has by selection or elimination lost the black birth-stripes; yet some of these exhibit, under the first month's age, gold stripes on a red field, presenting these stripes with hairs

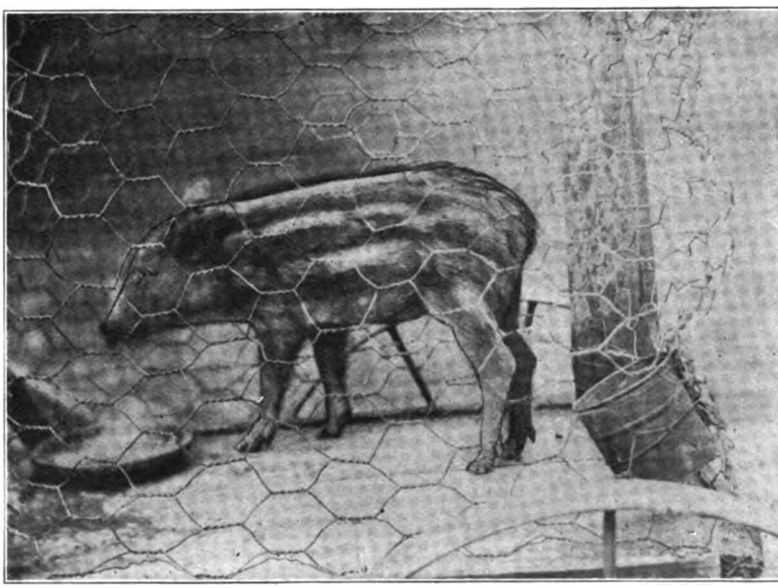


FIG. 1. SCROFA (SCHWARZWALD WILD) AT SIX WEEKS OF AGE.
Stripes disappear at four months of age, leaving a solid gray.

of a longer and coarser growth, as do the black stripes on young wild Scrofa.

The *Sus indicus* (domestic from China) does not exhibit these dorsal and other parallel stripes, and no stage of pigmenting in our hybridizing of the various breeds of this species has brought them out. Now when the wild Scrofa or its pure derivatives (the Tamworth and the feral swine from Arkansas) of a solid-hair pigmentation are hybridized with a right proportion of white from the White Yorkshire (*Sus indicus*), which we have accurately determined, the blended roan used for diluent—which must be free from "spot-habit"—we

get some roan-striped hybrids showing very plainly the seven longitudinal side and dorsal stripes, that stay on to full maturity. In the same brood, of course, we get also solid-pigment pigs of Mendelian proportion.

The chemist must know the strength needed in his reagent to produce reaction; and this applies in hybrid tests. We have a nearly universal law—that "the color-quantity in individuals is in relation to the color-sum of the two parents." This must be kept in mind; and in all pattern-making the design from the delicate tribal stencil must not be drowned with an over-abundance of pigment from the diluter, but only the required amount used to bring out its exhibit.

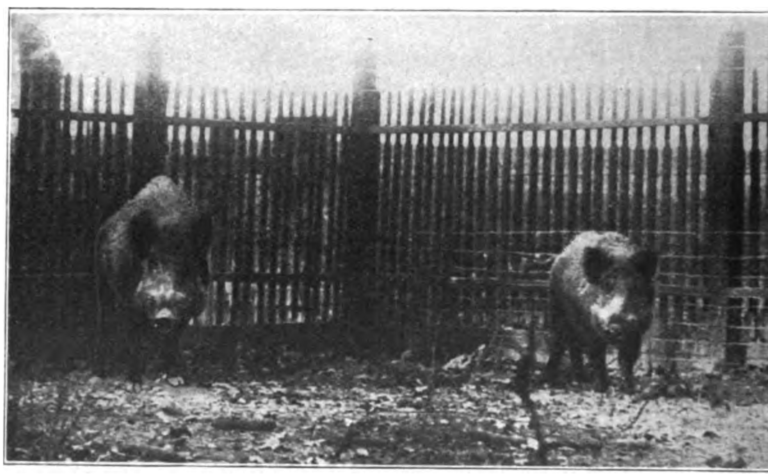


FIG. 2. MATURE SCROFA.

This pair direct from the Schwarzwald; the parents of pig shown in Fig. 1. Color a wild brown; by fading of hair-ends, gray. For this photograph we are indebted to Mr. August Busch, through whose kindness we have been able to maintain this species without inbreeding. The boar (to the left) is the sire of pig in figure 1.

The large English Yorkshire, an old breed, pure white in skin and hair, and now by elimination a nearly pure Indicus, has no latent stripes nor latent color-pattern, which we have proven by hybrid test with various pigmented breeds of his species, and on this account is an excellent reagent for determining adulteration in many other breeds. Its first cross with the red Tamworth should always be pure white in hair; and in a complex hybrid of these, i. e., three-eighths York and five-eighths Tamworth, when one of the parents is white and the other red, there results Mendelian segregation; but the whites are not white but light-red-roans with the seven longitudinal stripes that,

unlike the baby stripes of Scrofa, strengthen with age. All the combinations of Tamworth with Yorkshire fail to produce a spot or pattern other than the stripes, and a white belt around the body at shoulders, sometimes, in the fainter roans. This belt is supposed to be from the embryonic folding of the ectoderm cells that belong alike to the ox, swine, horse and India tapir. (See Spillman on *The Belt-Pattern in Mammals.*) It is placed more anteriorly on swine than on any other mammal.

With the reaction established in the Tamworth-York hybrids, then either breed may be used as a reagent for testing the purity in an indi-

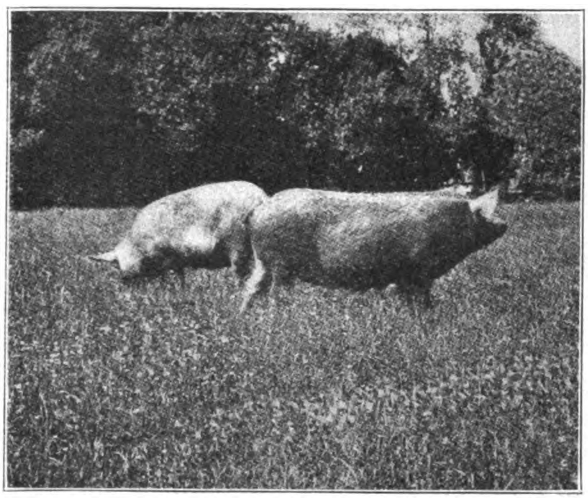


FIG. 3. PURE PEDIGREED ENGLISH TAMWORTHS.

Color always solid red, varying from yellow-red; bright red, to dark cherry-red; an excellent testing reagent in analytical tests.

vidual of the other breed; and we have made practical application of this, testing (sometimes adversely) supposedly pure animals of each of these breeds that were purchased from reputable foreign breeders. You will understand that the reagent must be uncontaminated and its purity known.

The Poland-China, an American, *Sus indicus* type, when crossed with the Yorkshire beget only clean whites. This Poland-China as now fixed is a solid black with the forefeet, forehead, and tail-switch white; and the spot-pattern that it formerly bore has been long eliminated; so that there is now no cell differentiation over the entire ectoderm, outside of the extremities named. This non-spot of pig-

ment cells on body of Poland-China is proven, when one is crossed on a red-roan York-Tamworth hybrid, by the resulting progeny dividing into one-half the brood clean all-whites. Now when the visibly pure Poland-China has even slight contamination of Duroc (red), a spot habit is brought out in reaction to same York or York-Tamworth reagent, this latent loin-spot reaction being previously found in the Duroc breed by a first-cross test with a pure York.

The Hampshire is a rather new breed, developed first, perhaps, in southern Indiana; and has by selection and elimination been given a

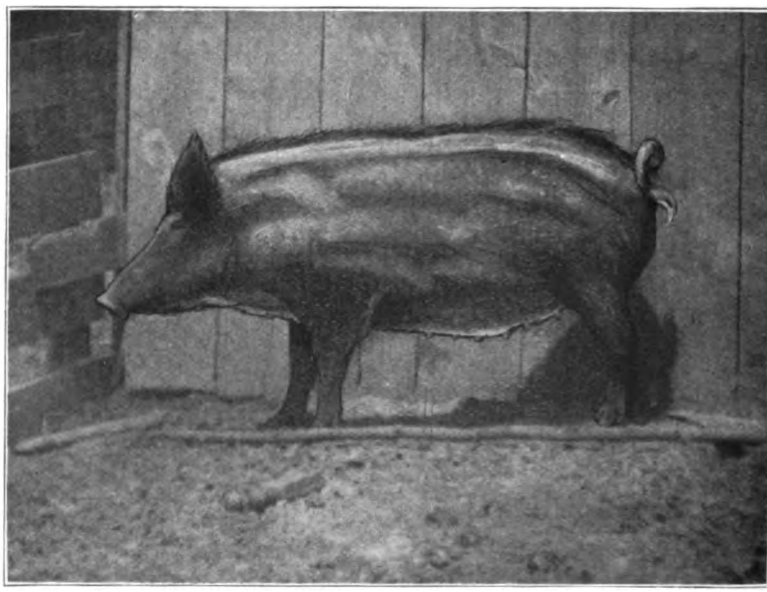


FIG. 4. A STRIPED RED-ROAN COMPLEX HYBRID.

Sired by a white first-cross Tamworth-Yorkshire; dam, a wild gray first-cross Tamworth-wild (in color a wild gray).

relatively "fixed" and hereditary color-pattern of solid all-black on posterior and anterior, and a white belt encircling around shoulders, enclosing all of front legs and feet.

Now this tribal stencil may be also drowned by overabundance of coloring from an all-black mate, as in the stripes of Scrofa; but like the latter, and as with Davenport's absorption from black to *Gallus bankiva* pattern, we may dilute the all-black Hampshire hybrid's pigment with an all-white cross and exhibit again its breed-pattern in perfection. The black ends may be also robbed of pigment, when

one parent is a dominant white; but when pigment is again furnished, the Mendelian percentage will have the belt-pattern restored.

In our experiments it seems that many times cells richest in sulphur, like horn, hoof, and hair, accept pigment differently to skin cells; and their colors appear to be regulated by different determiners. We have explanation for this in the catalytic action of chromosomes, but will not here give the details.

Heredity appears to be transmitted in units, the size and numbers of which can, possibly, be always learned by careful hybridizing of well-contrasted breeds, and purity-tested subjects to initiate. If the individual purity is unknown, the experiment is null.

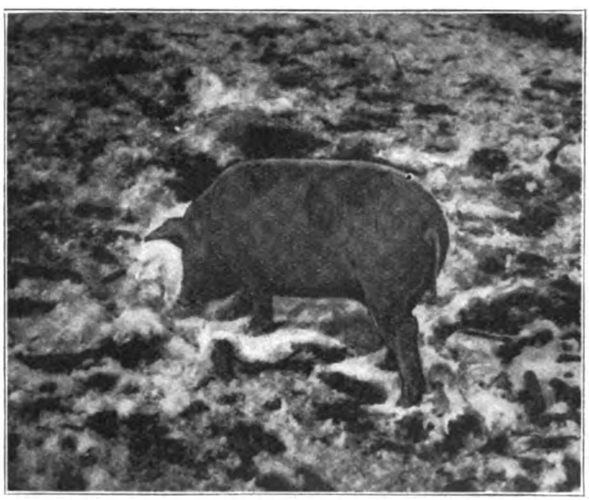


FIG. 5. IMPORTED BARROWFIELD, ESQ.

English large Yorkshire. The York has the typical Indicus skull from Scotland, and its ectoderm carries no latent pattern. Its absence of pigment, exaggerated skull formation, and striking mentality make it a valuable breed for a reagent.

The very uniform first-hybrids from two pure breds seem to show the rather stable molecular arrangement of their heredity determiners (the chromosomes); and one of these first-cross hybrids when bred to a third pure breed produces two classes of hybrids, each class of which is uniform with itself in many characters. Morgan has not agreed with this, and said: "The assumption of the separation of factors in the gametes is a purely preformation idea"—a stigma that the student does not enjoy; nevertheless, our herdsman accurately predicts the percentage of the two classes in three-breed hybrid broods, in every instance.

Empirical formulæ for hybrid analysis is of great importance in the testing of newly made-up breeds in ascertaining if undesirable but latent characters have yet been eliminated; and when proven pure with this analysis, a four-generation breed may be of equal "fixity" and standard value to one of prehistoric genealogy in its transmissive power.

The exact application of Mendel's law to all swine hybrids, where the initiative subjects have been proven pure and homozygous in germ, and the similarity of process in all sexual animals and plants

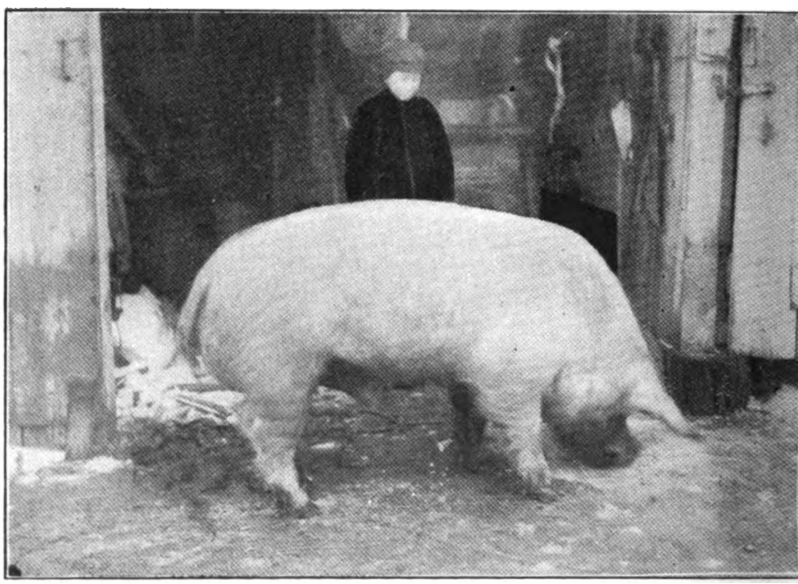


FIG. 6. WHITE SOW WITH BLACK LOIN AND SHOULDER.
A first cross Duroc-York. Spot habit from the red Duroc.

in chromosome reduction preparatory to fertilization, leads us to conclude that when pure they will all obey Mendel's laws absolutely; and when any marked deviation in hybridizing is found it is proof positive of contamination in one or both subjects, and we would suggest a careful breed analysis of each subject used in the cross.

Plant breeders have not always recognized that their seed subjects taken from an apparently isolated plat may have had the father blown in from another county whilst their direct experiment was carefully guarded by bagging the blossoms.

Mendelian observers have been slow to apply these genetic laws to anthropology, and the usual heterogeneity of unit determiners in man make the observation difficult to interpret. Ethics and legislation are against the direct experimentation of the genus homo, but on the borders of civilization many deductions could be possibly made from the hybrids of well-contrasted breeds. The black races are strongly color-dominant over white, and the *brunette*-white has perhaps greatly outnumbered the *blonde*-white throughout the South; yet a small percentage of red-haired and yellow-haired mulattoes may be found among the supposed double-cross mulattoes, i.e., children resulting from the union of two half-breeds; and there would be little doubt that one-fourth of the double-hybrids would have fair hair had all the white stock of the South been of fair-haired homozygous germ. (In discussing this with Professor Spillman, he suggests

FIG. 7. HAMPSHIRE POLAND-CHINA HYBRID.

A typical Hampshire pattern, excepting that it bears the white tail switch and hind feet of the Poland. Thirteen pigs were born in this brood, six of which were of this Hampshire pattern and seven with the clean white feet but with white spots on the black ends. (Photo by Spillman.)

that the Negro through long ages of "fittest" climatic selection has not developed one pigment-building unit, but many; even that there is a possibility that *all* of the chromosomes may assist in the making of pigment in the Negro.) Our observation of mixed-bred (mulatto) families seems to substantiate the idea, for in the skin colors of any numerous brood there are all the shades.

There are mental and morphologic tests in swine apparently as conclusive as are the pigment and pattern tests, which bring us nearer to the similitude of anthropos analysis. These we have not deter-

FIG. 8. A WILD GRAY.

A "wild gray" from same litter as number four, but photographed at a younger age. Note the short York face. In same litter was a female of close resemblance in color and skull, but bearing heavy bristles like the wild. In the same litter were two bright reds, besides the two roans described under cut number 4. The two reds resulted from the union of red determiners from the two red (Tamworth) grandparents.

mined from reactions, but by observation, and they may be classed among the invisible racial indices.

The Indicus was introduced into England through the Chinese hog, whose domestication is perhaps of remote antiquity; its genesis through only a long line of sty-kept ancestors has obliterated the filial attributes of the gregarious suidæ that was necessary to its preservation when in nature. The Berkshire and the Yorkshire both typical of the ancient Chinese swine in skull formation, can scarcely be driven through a hole in the fence. The father of the writers rarely failed to detect the otherwise invisible Berkshire taint by this racial

instinct. Yorkshire hybrids may be sorted back as with a sieve in driving a mixed drove of swine over a planked railway crossing. The gregarious instinct of the Tamworth is proven; and our herdsmen learn that an obstinate Tamworth, wild Arkansas, or a German wild, or their hybrids, may be quickly brought back into the moving herd by an offensive attack of the collies, whilst a Berkshire or a Yorkshire must be brought in by a spreading of jackets and a careful "soo-o-o-boy."

From our meager observation of strongly contrasted mental traits, under hybridizing, we are led to believe that the brain, or parts of it at least, are Mendelian, and F_2 hybrids of wild Scrofa × Indicus have given us well-defined return to the mentality of both species. That there is staining, partial blending, and modification of brain units, just as there are in pigment, pattern, and morphologic units, there can be no doubt. The Eugenics Committee recognize that man's heredity obeys the simple plant and animal laws of amelioration; then if right, his heredity must fit the laws of Mendelian unit-segregation, which is used alike in the analysis for purity and in the synthetic building up of better individuals and races.

In conclusion we will state our opinion, that all sexually reproducing animals and plants must strictly obey Mendel's laws in all their singly determined units; when there is apparent departure from these laws, under hybridizing, it is proof positive of impurity, in one or both of the two halves, of sexual chromosome-colonies, or a proof of the heterogeneity (mixed genesis) of one or both of the initiative individuals.

THE BLUE FOXES OF ST. PAUL AND OTTER ISLANDS, ALASKA[a]

JAMES JUDGE

Washington, D. C.

Two years ago a detailed account of the Blue Fox Industry on St. George Island, one of the Pribilof Group in Alaska, was published in the Annual Report of the American Breeders Association.[b] On this island the foxes are fed during the winter, are trapped mainly in corral or house traps, the choice animals are selected, branded and turned out for breeding purposes, and the poorest individuals killed for fur

[a] Submitted by Committee on Fur Bearing Animals. Vernon Bailey, chairman.
[b] Annual Report American Breeders Association, vol. v, pp. 325-340, 1909.

at the time when the fur is at its best. During the winter of 1907-08, 985 foxes were caught, 539 were released for breeding and 446 killed for fur.

During the winter 1909-10, the total catch was 778 of which 421 were released for breeders and 377 killed for fur.[c]

The fox industry on St. George Island is well established and is carried on up to the limit of food supply. In former years when the great numbers of seals and sea lions killed each year provided abundance of food the number of foxes killed for skins on the island up to 1889 averaged considerably over 1000 a year.

Still the cash value of the present yield of skins amounts to several thousand dollars annually. The greatest value of the industry however is in its demonstration of the fact that Blue Foxes can be bred up under semi-domestication on the islands of Alaska where the conditions are favorable, with every probability of success and profit.

The present paper deals with the foxes on St. Paul and Otter islands, also in the Pribilof Group.

Feeding.—The providing of artificial food for the foxes of St. Paul Island was begun in 1897, and has been continued every winter to the present time, regardless of the fact that for many years they ate little or none of it. Half rotten seal meat which proved so palatable to the foxes on St. George failed to attract their kindred on St. Paul. Both salt and dried salmon were likewise tried but found ineffective for the purpose of attracting the foxes to any particular point for regular feeding. In their ramblings about the animals would occasionally eat some of the food thrown out, but it seemed not to occur to them to return next day for more. It was not until 1907 that they showed any training at all. They are very fond of oil, or fat of any kind, and during the fall of that year a large quantity of whale blubber came ashore on Lagoon Reef; and subsequently a number of foxes were observed feeding on it daily. To facilitate this feeding men were detailed to cut the blubber into small pieces.

As the blubber became scarce the following spring, all the salmon on hand was freshened, thrown out, and eventually eaten as were also the carcasses of two mules, shot the preceding autumn. During the winter of 1908-09, salmon, sea lion meat and hog offal were supplied in varying quantities and eaten by the foxes. The success achieved encourged further efforts, and as other food was not available, pits were excavated during the summer and fall of 1909 in which seal meat and the offal from the killing fields were buried. These

[c] Fur Seal Fisheries of Alaska in 1909. Bureau of Fisheries Doc. No. 735, p. 46, 1910.

pits were opened the following winter and the contents exposed for fox food. Most of that first thrown out was eaten by the "chickies" a specie of gull common on the island. It became necessary therefore to devise means whereby the meat set out would be available for the foxes, but out of reach of the gulls. While food was exposed constantly from late in October, it was not until the middle of January that the animals came in any considerable numbers for it. From the latter date however a greater or less number partook of the food daily, until the entire supply, together with all the salmon on the station, was consumed. At North East Point, 12 miles from the village, seal meat was also stored, but little of it was eaten; the foxes in that neighborhood apparently preferring what remained of a number of sea lions, killed for their hides the preceding spring. The total amount of food preserved for, and consumed by the foxes last winter offers encourgement to the hope that possibly the method of trapping which followed the successful feeding of foxes on St. George, may yet become practicable on St. Paul.

Trapping.—Being unable to train the foxes to come to the village for food while the skins were prime, and therefore unable to inaugurate the methods of foxing pursued on St. George, the natives were permitted to use their steel traps for a period of six days beginning November 28. During this interval 130 blue and 35 white fox skins were secured on St. Paul Island.

On December 6 a party of five men went to Otter Island remaining there until December 14, during which time 1 white and 19 blue were taken, making a total catch for both islands of 149 blue and 36 white skins.

This proportion of white skins is unusually large, comprising nearly 20 per cent. From the statistics available it appears that in former years the percentage of white skins in the catches of St. Paul varied between 1 and 10 per cent. Why this percentage of white has increased is not clear. An examination of the white skins showed them all blue at the base, thus confirming their island origin, and confusing the theory that some of them had arrived from the mainland on the ice.

It is interesting to note that the percentage of white foxes in the catches on St. George Island tallied closely with that on St. Paul down to 1901. Since the latter date steady and continuous efforts have been put forth for the extermination of white foxes on St. George Island with the result that the catch of white there is less than 4 per cent annually.

Statistics.—Divided as to sex, 76 blue and 19 white, or 51.3 per cent of the St. Paul and Otter Island catch last year were males.

Immediately after death and prior to being skinned 93 males and 76 females were weighed individually as caught. The weights on St. Paul varied between 8½ and 15 pounds for males, and 7 and 13 pounds for females. These weights indicate that the animals trapped had been well supplied with food and were in good physical condition.

The weights taken on Otter Island varied between 7 and 10½ pounds for males and 6½ and 9 pounds for females, indicating that those animals had been underfed and were in poor condition. The relative abundance or scarcity of food, suitable for foxes on the respective islands, is apparently emphasized in the weights of the animals inhabiting them. The St. Paul foxes have food in comparatively plenty from May until January furnished by the birds, seal rookeries and killing fields. Otter Island foxes have food in abundance from May until September only, as there are no seals on that island. The beaches of either island yield more or less food, but the amount is uncertain and contingent upon a variety of events; and when the ice floe arrives in January, as it usually does, this supply is entirely cut off. The foxes then resort to the open pools in the floe where birds may be found feeding or resting; and they also cross from one island to the other. During these migrations or sojourns on the ice many are carried to sea and lost.

Of the animals examined 39 were yearlings and 55 males and 35 females were of breeding age, that is to say they were one year and upwards in the spring of 1909. If the females capable of bearing young in the spring of 1909, actually did so, presuming of course that a similar distribution as to age existed among the animals which escaped the trap, the percentage of young born, which reached maturity was very small, as litters of new born foxes are known to vary between 5 and 12 in number. The immense infant mortality among blue foxes is well known but the exact causes thereof, or satisfactory methods of checking it, have not yet been discovered.

The contents of the stomachs and intestines of the animals killed, nearly all of which were examined, were about the same as those found in the St. George Foxes and reported two years ago; but the variety of these contents was less extensive on Otter, than on St.Paul Island.

The average length of the 76 blue male skins secured, when dried and ready for market was 32.3, average width 10.2, average length of tail 15.5 inches. The average length of the 73 blue females taken

was 29.4, average width 9.3, average length of tail 15 inches. Skins of the same size animals will vary in length and width, depending on the style of frame used for drying.

The skins secured on St.Paul were of an unusually superior quality long furred, dark and lustrous; while those taken on Otter Island were of inferior quality, being short furred, almost lusterless, and many of them streaked with gray.

Otter Island skins are always of a low grade, or at least have been in recent years when trapping has been carried on there.

It would seem that the extra hard conditions under which these animals live during the greater part of the year, is reflected, not only in the weight of those trapped, but also in the inferior quality of the fur produced.

The conduct of the Otter Island foxes, on the arrival of the trapping party was pathetic. Several of them appeared at the landing place and showed considerable curiosity as the boat was taken from the water. They were very hungry. Keeping only a few feet away they followed the natives around, and when two hair seals and a few birds were shot, they greedily devoured the offal which was left for them. That night they hung about the watch house contesting with each other for the bits of meat and bread thrown out, and taking their departure only after two of their number had been killed by pieces of fire wood in the hands of the natives, and six others had been caught in the traps set within a few feet of the house.

A STUDY OF THE FIRST, SECOND AND THIRD-YEAR EGG PRODUCTION OF WHITE LEGHORN HENS

CLARA NIXON

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At the present time, when the prevalence of various chick diseases makes the rearing of chicks sometimes uncertain and often expensive, the question of how many years hens will produce eggs in profitable numbers is an important one. The useful life of a hen is short at best. If, however, she may be kept for two or three years instead of being removed from the flock at the end of the first season, the number of mature pullets needed to maintain the size of the flock is materially decreased. It is the plan in this study of the egg-production of

eighty-eight White Leghorn hens to show, first, whether hens which produce well for any particular year are likely to give good egg production for a longer period; second, whether it is possible to judge from the egg record of any particular year what is likely to be the egg production of the same hens during succeeding years.

The material on which these calculations are based was obtained from trap-nest records of six flocks of White Leghorn hens. Only records covering the full three years of production were chosen. The flocks were under experiment, and the hens received, in many cases, different rations, or were fed by different methods. These conditions may have influenced to a considerable degree the production for any one or all of the years. The study deals with individual production, and does not consider rations or methods of feeding. Since the individuals studied are so few, and the conditions of feeding so varied, the results should not be considered as conclusive or of general application.

The population was arranged into classes according to the egg production, the classes varying in all cases by 25 eggs. The divisions were made with reference to the three-year production and also according to the first-year, second-year, and third-year laying records.

In each class were placed the individuals which showed the degree of the character in question corresponding to the lower limit of the class. For instance, class 75–100 contains hens laying 75 or more eggs, but less than 100. Class 100–125 includes hens which laid 100 or more eggs, but less than 125.[a]

As a result of an attempt to discover whether hens which lay well for any particular year are likely to produce correspondingly well for three years, the following specific questions have arisen:

(1) Is the first year record of a hen in any degree likely to indicate her total production for three years?

In order to answer this question, it is necessary to compare two characters of a population, showing to what degree a change in one character is accompanied by a change in the other.

In Table 1 is shown the three-year production as subject of comparison, with the first year production as relative.

Since the same hens are considered in both arrangments, each

[a] The usual constants were determined, calculations being made by the "short method" as given by Dr. Eugene Davenport in "*Principles of Breeding*," and by Eugene Davenport, Henry L. Rietz, and others in the bulletins of the Illinois Agricultural Experiment Station. Results for the constants were carried to the fourth decimal places, the value of the third figure being increased if the fourth figure exceeded 5. The modes and variation constants which were obtained by the calculations are shown later (Tables 9 and 10).

hen must be represented in a class belonging to each of the characters. For example, the second line of figures from the top of the table represents the hens which laid 100–125 eggs in three years. One of these hens is in the first column from the left of the table, showing that she laid 0–25 eggs the first year. The other is in the second column from the left, indicating a first-year production of 25 to 50 eggs.

The table shows that the hens which laid more eggs in three years tended to lay the larger number of eggs the first year. For instance, a

TABLE 1.—*Correlation between the total egg-production per hen in three years, and the egg-production per hen for the first year of laying.*

[$r = 0.7501 \pm 0.0314$.]

Total egg production per hen in three years.	First year egg production per hen. 0 to 25	25 to 50	50 to 75	75 to 100	100 to 125	125 to 150	150 to 175	175 to 200	200 to 225	Totals.
75–100			1							1
100–125	1	1								2
125–150			2							2
150–175	2	1	2	1						6
175–200		3	4	1	2					10
200–225	1		3	5	1					10
225–250			3	3	3					9
250–275			1	3	2					6
275–300			3	2	1	1				7
300–325				3	4	1				8
325–350				2	5	3				10
350–375					4	1	1			6
375–400					1	3	1			5
400–425				1						1
425–450					2	1	1		1	5
Totals.	4	5	19	21	25	10	3		1	88

NOTE:—The limits of the three year classes are shown at the left of the table (the lowest at the top, and increasing by units of 25 toward the bottom), with the total number of hens at the extreme right. The limits of the first-year classes are shown at the top of the table (the lowest at the left), with the total numbers of hens in the classes shown at the bottom.

line drawn vertically at the right of the 75–100 class, and another line drawn horizontally below the 275–300 class, will separate into a smaller table at the lower right-hand corner the hens which laid over 300 eggs in three years and which also laid more than 100 eggs the first year. The question is to what extent the tendency is likely to pervail in other flocks. This probability is mathematically expressed in the correlation coefficient (r).[b] In this case, $r = 0.7501 \pm 0.0314$.

[b] The value of this constant must come between +1 and −1. If $r = +1$, it shows that the characters are likely to be found together, and that an increase in one indicates a corresponding increase in the other. If $r = -1$, an increase in one will necessitate a corresponding decrease in the other. If $r = 0$, they exist, or increase and decrease, independently of each other.

If one may judge from this population, there is a probability of more than 75 per cent that the poultryman, in keeping good first year layers, keeps hens which will give good total production during three years.

(2) Is the second-year egg production likely to be at all proportionate to the three-year production?

TABLE 2.—*Correlation between the total egg-production per hen in three years of laying, of 88 hens, and the egg-production of the same hens for the second year.*

[$r = 0.8491 \pm 0.0201$.]

Total egg production per hen in three years.	Second year egg production per hen. 0 to 25	25 to 50	50 to 75	75 to 100	100 to 125	125 to 150	150 to 175	175 to 200	Totals.
75–100	1								1
100–125		1	1						2
125–150	1		1						2
150–175	1	1	4						6
175–200		1	7	1	1				10
200–225		1	5	3	1				10
225–250			3	5	1				9
250–275			2	2	2				6
275–300				2	4	1			7
300–325			1	2	2	3			8
325–350			1		6	3			10
350–375					1	4	1		6
375–400				1	1	2	1		5
400–425						1			1
425–450							3	2	5
Totals....	3	4	25	16	19	14	5	2	88

In this table, the three-year production (as subject) and the second-year production (as relative) are compared.

The range of variation in production was not quite as great as in the first year, but the average tendency of the population was toward higher production during the second year. A division of this table at the classes as suggested for Table 1 will show that thirty of the thirty-five hens which laid more than 300 eggs in three years laid over 100 eggs the second year. For this table the value of $r = 0.8491 \pm 0.0201$, indicating nearly 85 per cent probability that the second-year egg production of a flock will be proportionate to the three-year record, judging from these records.

(3) Can the third year production of a flock of hens be considered an indication of the three year record?

TABLE 3.—*Correlation between the total egg-production per hen, of 88 hens, in three years, and their production per hen for the third year of laying.*

[$r = 0.6240 \pm 0.0439$]

Total egg production per hen in three years.	Third year's egg production per hen. 0 to 25	25 to 50	50 to 75	75 to 100	100 to 125	125 to 150	150 to 175	Totals.
75–100	1							1
100–125		1		1				2
125–150	1		1					2
150–175		2	1	2	1			6
175–200	2	1	4	3				10
200–225		1	5	2	2			10
225–250		1	4	2	2			9
250–275			1	4	1			6
275–300			1	2	4			7
300–325			2	3	2		1	8
325–350				3	3	4		10
350–375			1	2	2	1		6
375–400					4	1		5
400–425							1	1
425–450			1	1	1		2	5
Totals....	4	6	21	25	22	6	4	88

This table also shows the three-year production arranged as subject, but with the third-year production as relative. A tendency toward higher production on the part of the hens which had laid less eggs in previous years, and toward decreased production by the more prolific hens of former seasons is shown. Only twenty-two of the thirty-five hens which laid more than 300 eggs in the three years, laid over 100 eggs the third year. The correlation coefficient of this comparison would indicate that the chance of a proportionately high third-year production by a flock of hens as compared to the three-year record is less than 65 per cent.

Table 4 shows, in a different way, the tendency in egg-production for the different years. The hens are placed in classes, as before, according to their three-year laying. The tendency of many of the less prolific hens toward increased production as the years advanced, and of the more prolific hens toward decreased production, is evident. The average, however, of the hens which laid less than 300 eggs in three years shows a slight decrease from first to third, while the average of the hens producing more than 300 eggs in this period was highest the second year, with a marked decline for the third. An important showing is that the average number of eggs laid in the three years,

TABLE 4.—*Egg production as shown in original data.*

Classes, arranged in order of total production, 3 years.	Number of hens.	Egg production (average) by classes.			
		1st year.	2nd year.	3rd year.	3 years.
75–100	1	68.	10.	7.	85.
100–125	2	15.5	38.5	58.0	112.0
125–150	2	60.0	28.5	36.0	133.5
150–175	6	46.8	49.3	64.0	160.1
175–200	10	66.8	64.1	54.6	185.5
200–225	10	75.1	70.2	70.7	216.0
225–250	9	83.4	79.8	74.2	237.8
250–275	6	89.8	89.6	86.5	266.0
275–300	7	85.4	105.1	96.4	287.0
Total	53				
Average of hens which laid less than 300 eggs		72.2	71.2	69.6	215.1
300–325	8	109.0	109.4	93.0	311.4
325–350	10	111.1	115.2	112.3	338.6
350–375	6	126.8	135.8	101.5	364.1
375–400	5	139.8	106.6	115.4	381.8
400–425	1	99.0	135.0	170.0	404.0
425–450	5	152.6	167.6	113.8	434.0
Total	35				
Average of hens which laid more than 300 eggs		123.0	127.1	108.3	358.4
Average—all classes		92.4	96.9	86.2	272.1

by the lower producers, was, for each year, distinctly below that of the higher producers. If the hens which laid fewer eggs during the first year had been removed from the flock at the end of that period, the average production in the flock would have been higher during the second and third seasons, and the consequent profit per hen greater.

The problem as to whether one may judge from a single year's production what is likely to be the egg record for the succeeding year or years, gives rise to other questions.

(1) Is the egg record of the first year any indication of the degree of prolificacy during the second year?

In Table 5, the first-year production is used as the subject of comparison, and the second-year production as the relative. The tendency of the hens which laid well during the first year to lay well during the second is shown. Twenty-seven of the thirty-nine hens which laid 100 or more eggs the first year, laid 100 or above during the second year, while only ten of the forty-nine which laid less than the 100 eggs the first year gave 100 eggs the second. As indicated

TABLE 5.—*Correlation between the egg production per hen of the first year of laying, and the production during the second year.*

[$r = 0.5484 \pm 0.0503$.]

First year egg production per hen.	Egg production per hen during the second year of laying. 0 to 25	25 to 50	50 to 75	75 to 100	100 to 125	125 to 150	150 to 175	175 to 200	Totals.
0–25	....	1	2	1	....	....	....	....	4
25–50	....	1	2	1	1	....	....	....	5
50–75	2	1	9	3	4	....	....	....	19
75–100	1	....	6	6	5	3	....	....	21
100–125	....	1	5	2	5	9	3	....	25
125–150	....	....	1	3	2	2	1	1	10
150–175	....	....	....	....	2	....	1	....	3
175–200	....	....	....	....	....	....	....	....	0
200–225	....	....	....	....	....	....	....	1	1
Totals....	3	4	25	16	19	14	5	2	88

by the value of r, the probability that the egg production of the first year will be followed by proportionate production for the second year is about 55 per cent.

(2) Is the egg production for the first year at all likely to be an indication of the third-year production?

TABLE 6.—*Correlation of the production per hen during the first year of laying, and the production per hen during the third year.*

[$r = 0.1530 \pm 0.0702$.]

First year egg production per hen.	Third year egg production per hen. 0 to 25	25 to 50	50 to 75	75 to 100	100 to 125	125 to 150	150 to 175	Totals.
0–25	....	....	....	2	2	....	....	4
25–50	....	1	2	2	....	....	....	5
50–75	2	2	5	4	6	....	....	19
75–100	....	2	6	6	3	2	2	21
100–125	2	1	6	7	5	2	2	25
125–150	....	....	1	3	4	2	....	10
150–175	....	....	....	1	2	....	....	3
175–200	....	....	....	....	....	....	....	0
200–225	....	....	1	....	....	....	....	1
Totals....	4	6	21	25	22	6	4	88

Table 6 shows the first-year production as subject and the third-year production as relative. The distribution for the third year is more even, the lower producers of the first tending toward greater

production and the higher producers toward lower production. The range of variation is less by 50 eggs. As indicated by the value of r, the likelihood of correspondingly high egg production during the third year, by hens which have laid well the first season, is about 15 per cent, a low correlation.

(3) Is the second-year record any indication of the egg production during the third year of laying?

TABLE 7.—*Correlation between the egg-production per hen for the second year of laying, and that of the third year.*

[$r = 0.3973 \pm 0.0606$.]

Second year egg production per hen.	Third year egg production per hen. 0 to 25	25 to 50	50 to 75	75 to 100	100 to 125	125 to 150	150 to 175	Totals.
0–25	1	....	2	....	....	....	....	3
25–50	....	....	....	4	....	....	....	4
50–75	3	4	7	6	3	1	1	25
75–100	....	1	5	3	6	1	....	16
100–125	....	1	3	7	6	2	....	19
125–150	....	....	3	3	5	2	1	14
150–175	....	....	....	1	2	....	2	5
175–200	....	....	1	1	....	....	....	2
Totals....	4	6	21	25	22	6	4	88

In this table, the second-year production is arranged as subject and the third-year production as relative. The grouping of the higher and lower producers around a central point is much more uniform than in previous tables. According to this comparison, the chances are less than 40 per cent that the good second-year layers will give correspondingly good production the third year.

The low correlations do not show, however, that the egg-record of one year may not be used as a basis for culling the flocks to be kept for the next year's production. The following table shows the average performance of the the eighty-eight hens, as divided into classes according to their first-year production.

Computations from the original data show that the hens which laid above 100 eggs the first year averaged 115 the second, and 93 the third: while those which laid less than 100 eggs the first year averaged 76 eggs the second year and not quite 81 the third. There was, of course, great individual variation in production.

The tendency toward greater prolificacy on the part of the hens which had given lower production, and toward the production of comparatively fewer eggs by the better layers of the first year, is marked.

TABLE 8.—*Egg-production per hen for each year and for three years (as shown in original data).*

Classes arranged according to first year production.	Number of hens.	Egg production per hen (average in classes). 1st year	2nd year.	3rd year.	3 years.
0-25	4	11.7	52.1	96.0	160.0
25-50	5	36.0	66.8	62.0	166.8
50-75	19	64.1	68.3	73.0	205.6
75-100	21	84.9	89.2	89.3	263.4
Total	49				
Average production of hens which laid less than 100 eggs the 1st year		59.8	76.1	80.7	222.5
100-125	25	113.5	108.9	86.3	308.8
125-150	10	134.1	122.0	101.9	358.0
150-175	3	169.3	125.0	100.3	394.6
200-225	1	213.0	176.0	53.0	442.0
Total	39				
Average production of hens which laid more than 100 eggs the first year		125.7	115.3	93.1	331.5
Average of all classes		92.4	96.9	86.2	272.1

It is clearly shown, however, that the average production of the better hens was distinctly above that of the lower producers of the first year, especially for the second year.

The average egg production for the entire population was greatest the second, and least the third year.

The individual variation within the classes, was considerable.

It would appear from these calculations that the first-year egg record was, in this case, a fairly safe basis for the selection of second-year layers. The first-year record was not, however, a reliable indication of third-year production, nor was the second-year production a satisfactory basis of selection for the third-year flock. The results might differ greatly, however, with hens kept under different conditions and methods of feeding, or with hens of other breeds.

SUMMARY

These calculations show that—

(1) Hens which laid well the first year tended to lay well during three years of production.

(2) Hens which gave good production the second year were likely to be the ones to give good production in three years.

(3) The third-year production was less indication of a good three-years record than was that of either the first or the second year.

(4) The average production of the second year was greatest, and that of the third year least, in the three years of laying.

(5) Hens which made a good first-year record tended to lay comparatively fewer eggs the second year, but their average production was still above that of the hens which laid fewer eggs during the first year.

(6) Hens which laid well the first year could not be depended upon for correspondingly high production for the third year, though their average production was somewhat above that of the less prolific first-year layers.

(7) Hens which laid well the first year tended to decrease in production for the second and third years, and those which laid fewer eggs the first year tended to give higher production as the years advanced.

(8) Wide individual variation as to the comparative egg-production of the first, second, and third years was evident.

Below are given the modes and variation constants which resulted from these computations.

TABLE 9.—*Modes and constants of variation.*

	Modal class.	Mean.	Standard deviation.	Coefficient of variability.
Total egg production per hen (3 years)	175–200 200–225 325–350	271.307 ± 6.1366	85.349 ± 4.3395	31.458 ± 1.7268
Egg production per hen for first year of laying	100–125	92.614 ± 2.6925	36.571 ± 1.8594	39.487 ± 2.3077
Egg production per hen for second year of laying	50–75	95.455 ± 2.7839	38.720 ± 1.9687	40.564 ± 2.3770
Egg production per hen for third year of laying	75–100	87.784 ± 2.4463	34.023 ± 1.7300	38.758 ± 2.2477

TABLE 10.—*Correlation between periods of egg-production.*

	Coefficient of correlation.
Total production per hen (3 years), and first-year production	0.7501 ± 0.0314
Total production per hen (3 years), and second-year production	0.8491 ± 0.0201
Total production per hen (3 years), and third-year production	0.6240 ± 0.0439
First-year production per hen and second year production	0.5484 ± 0.0503
First-year production per hen and third-year production	0.1530 ± 0.0702
Second-year production per hen and third-year production	0.3973 ± 0.0606

Acknowledgment is due to the department of plant breeding of the New York State College of Agriculture for facilities of study, and to Prof. H. H. Love of that department for suggestions and criticism of work.

THE STUDY OF HUMAN HEREDITY: METHODS OF COLLECTING, CHARTING, AND ANALYZING DATA[a]

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David F. Weeks, E. R. Johnstone,
Henry H. Goddard

The following methods are in use at the Eugenics Record Office at Cold Spring Harbor, Long Island, the New Jersey State Village for Epileptics, at Skillman, and the Training School for Backward and Feeble-Minded Children, at Vineland, N. J.

1. THE FIELD WORKER

For many years the better organized hospitals and institutions for defectives have kept family histories of the patients. The information obtained from application blanks, physicians' examinations and replies received from letters sent to relatives and physicians have been compiled and tabulated and deductions have been drawn from them. But it has for some time been apparent that such family histories are far from satisfactory and that a better way to get at the method of inheritance of epilepsy, feeble-mindedness and the various forms of insanity and criminality is by means of a field worker, who goes to the homes and interviews persons that can and will give the desired information.

Besides the research work, the field worker performs many of the services that usually fall under the head of purely social worker. In many cases patients who have not heard from friends or relatives in years are brightened by the visit of the field worker and look forward to her return in the hope that she may bring them news of their friends. Discharged patients are visited by the field worker whenever possible in order to keep the institution in touch with them. Her visits to relatives, physicians and others establish a friendly feeling toward, and an intelligent understanding of, the institution and its work.

When connected with an institution, the field worker (who for the purposes of many studies is preferably a woman) first learns all she can about the patient from the material at the office, such as correspondence, application blanks, records of medical and psychological examinations. Addresses of friends and relatives and other informa-

[a] This article was originally published as: Eugenics Record Office Bulletin No. 2, and is a reprint of the same.

tion that may be helpful in locating them is recorded and put in form for the worker to take with her. Just before starting out to visit the relatives and friends, the field worker visits the patient in his ward or cottage. This is done in the manner of a friendly visit. She learns from the patient all that he or she can tell about the friends and relatives, especially with reference to their addresses, etc. The patients enjoy these visits, and are often able to give very useful information.

Everything now being ready for the visit to the home, the field worker, armed with recent personal knowledge of the patient, which assures her cordial welcome, visits the home and interviews the relatives, friends and family physician. To secure satisfactory results, sympathetic and confidential relations must always be maintained. It is better to leave some details to another visit than to have relations at all strained. The field worker's constant endeavor must be to establish a feeling between the family and institution that will assure her of a welcome at any time with kindly coöperation, and to this end she sacrifices minor details that would naturally come on return visits. The field worker endeavors to see as many relatives as possible. In this way facts omitted or overlooked by one are often recalled and told in full detail by another, and by this means information already obtained is confirmed. Every additional interview is sure to reveal new facts.

Addresses of relatives who live in other sections are recorded to be used later by an investigator in that section. References to foreign countries are also kept, with the town, and wherever possible, the street address. In the case of foreign born parents, an endeavor is made to obtain data relative to the time of immigration, the town from which they came, and other information that may be useful.

Whenever the field worker learns of any defectives who need institutional care, their names and addresses are obtained, and filed with the other material. By this means useful information is available when application is made for admission to institutions.

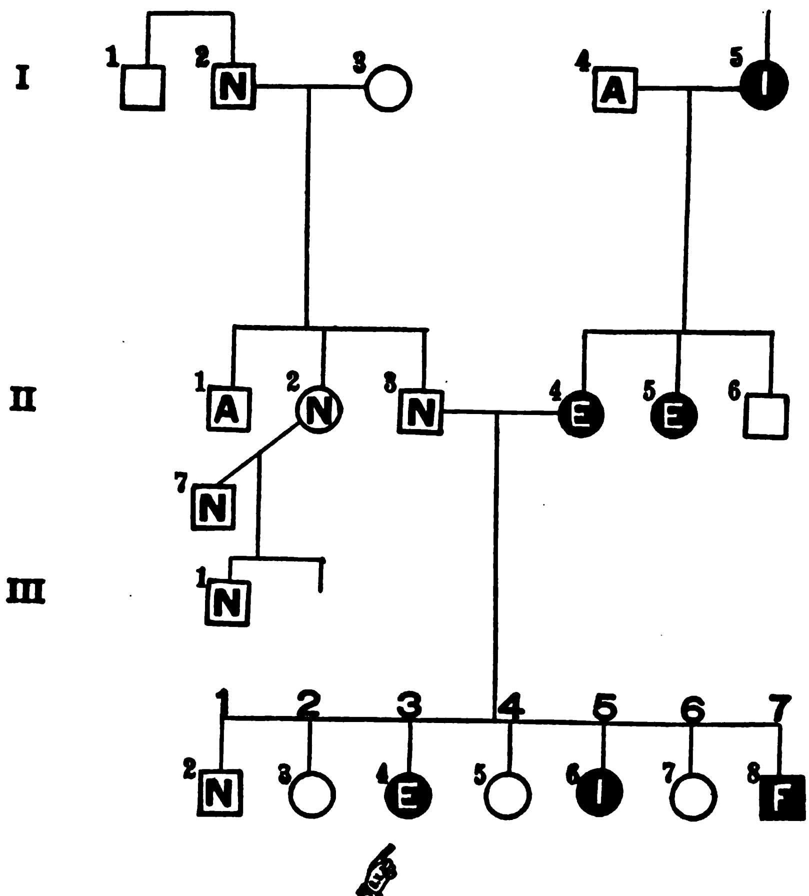
As collected, the data are carefully recorded, and the pedigree chart made of the family. This is then put in permanent form on a sheet of white paper 8 x 10½ inches, with such notes and symbols as have been adopted to designate certain traits. A full description, with all details, is typewritten and filed with the chart.

2. THE CHART (PLATE I)

The plan of charting adopted is based on the decisions of a committee of the American Association for the Study of the Feeble-

PLATE I.

Example of a simple pedigree chart.



Minded held at Lincoln, Ill., in 1910. This committee consisted of Superintendent D. R. Johnstone and Dr. H. H. Goddard, of Vineland, N. J., and Drs. A. C. Rogers of Faribault, Minn., Wm. Healy of Chicago, Ill., Wm. T. Shanahan of Sonyea, N. Y., and David F. Weeks of Skillman, N. J.

The system is a rectangular one, the symbols for the individuals (*individual symbols*) of a fraternity (full brothers and sisters) being on the same horizontal line, with each later generation placed below the next earlier. Male individuals are indicated by squares, females by circles, suspended by vertical lines (*individual lines*) from the horizontal line. Members of one fraternity are connected by the same horizontal line. The rank of birth in the fraternity is indicated by a serial number placed immediately above the *fraternity line*. When the sex is unknown the square or circle is omitted from the end of the individual line. The fraternity line is connected by a vertical line (*descent line*) to a line joining the symbols of father and mother (*mating line*). The mating line may be a short horizontal one or oblique, passing from one consort to the other as emergencies of space decide. Dotted mating lines are used for illegal unions. When a marriage of one of the individuals of a fraternity who occupies a middle position in the series is to be represented, the consort is placed below and to the right or left of the circle or square and joined to it by an oblique line from which is dropped a *descent line* meeting the fraternity line. In the case of illegitimate children, the descent line is dotted.

For purposes of reference from description to chart each sheet of a pedigree is numbered serially with Arabic numerals. On each sheet the generations are numbered serially at the left margin with Roman numerals (I, II, III, etc.) beginning with the oldest generation. In each generation each individual symbol is numbered with Arabic numerals from left to right. In the text reference is made to an individual on the chart by sheet, generation and individual number. Thus 1, II, 17 means the first sheet, II generation, 17th individual symbol from the left. For the sake of uniformity in charting the families, the paternal side of the family is placed at the left of the chart, the maternal side at the right.

(*For display charts*. As a matter of convenience and as an aid in tracing the patient's immediate family, showing at a glance the lines of paternal and maternal descent of the defect, the descent line connecting the paternal side may be made green. Red may be used for the lines connecting the individuals on the maternal side. That the patient's symbol may stand out more prominently and make the reading of the chart easier, the fraternity to which he or she belongs may be dropped below the others.)

Besides the lines and individual symbols a nomenclature is used that gives in brief much information for the interpretation of the

chart. The following capital letters are used inside or around the individual symbols as follows:

A	alcoholic, decidedly intemperate,	M	migrainous,
B	blind,	N	normal,
C	criminalistic,	Ne	neurotic,
D	deaf,	P	paralytic,
E	epileptic,	S	syphilitic,
F	feeble-minded,	Sx	sexually immoral,
G	gonorrheal,	T	tubercular,
I	insane,	W	vagrant (tramp, confirmed runaway).

An index hand points to the individual whose heredity is being studied.

A line under a symbol indicates that this individual is or has been an inmate of some institution.

A small black disc at the end of an individual line indicates a still-birth or miscarriage.

When the individual is the subject of several defects or diseases, the additional letters are arranged around the individual symbol. Symbols for traits that are not designated above are written beneath the individual symbol. When no letter accompanies the individual symbol it means that no definite data had been secured at the time the chart was made. The trait—alcoholism, criminality, deafness, epilepsy, feeble-mindedness, insanity, etc.—which the field worker is chiefly studying may be called the primary trait for the chart or pedigree. An individual showing the primary trait is represented by a solid symbol, printed (if desired) in color with the corresponding letter intaglio.[b] These symbols are shown in full size in Plate V.

In studies on insanity it is suggested that qualifying lower case letters, used singly or in combination, should, whenever possible, be added to the letter I, e. g.:

a alcoholic insanity,
d dementia præcox,
g general paralysis of the insane,
m manic depressive insanity,
p paranoia,
s senile dementia,
t traumatic insanity.

[b] Red is being used for epilepsy, green for insanity, violet for criminality, black for feeble-mindedness. When the individual does not show the primary trait or associated secondary trait he is marked "N," but this does not necessarily mean that he is normal in all respects.

On the pedigee chart, b stands for born; m, for married; † or d, for dead or died; † (or d) inf. means died at or before two years of age; † (d) young, means died before the age when the trait normally develops or is detectable; e. g., with feeble-mindedness before six years; with epilepsy before fourteen; with insanity before twenty.

In case other traits or causes of death are given on the chart they may be abbreviated as follows:

bd Bright's disease,
ca cancer,
cb childbirth,
ch chorea,
cr cripple,
df deformed,
dp dementia præcox,
dt delirium tremens,
dy dropsy,
ec excentricity,
en encephalitis,
go goitre,
gp general paralysis of the insane,
hy hysteria,
id ill defined organic disease,
kd kidney disease,
la locomotor ataxia,
md manic depressive insanity,
np neuropathic condition,
obs obesity,
pa paranoia,
pn pneumonia,
sh shiftlessness,
sm simple meningitis,
sb softening of the brain,
sco scoliosis,
sd senile dementia,
su suicide,
va varices, varicose veins,
ve vertigo,
x unknown,
? implies doubt.

When preceded by a † (or d) the term indicates the cause of death.

In making the charts rubber stamps may be used to advantage. Standard sizes of these may be obtained from Lewis F. Walton, 12 South Fourth Street Philadelphia. Other lettering may be done with a typewriter. (Plates III, IV.)

3. THE DESCRIPTION

The full description of an individual, as herein contemplated, comprises the following thirteen points. It is obtained for each in the family so far as practicable.

1. Name (maiden name of all married women; method of spelling surname preferred by the family to be ascertained and used. First time field worker uses a surname in her report it is to be written in Gothic capital letters, e. g., DE BOW).

2. Sex, if not sufficiently indicated by name (Frances, Francis; Jessie, Jesse; Marion, Marian; etc., frequently confused).

3. Date of birth. (This gives order of birth, age at time of interview, age at death, if dead, etc. Should be accurate to the month. Useful for reference to town and vital records.)

4. Place of birth. (Tells at least where mother was at given date and probably locates entire family; frequently assists in helping to connect with related families in same general locality; locates town where birth records may be sought.)

5. If dead, date of death or age at death approximately. Essential in getting proportions of affected among those who reach the *age of incidence.*)

6. Cause of death. (Get the best diagnosis possible, inquiring of family physician where practicable and learn if any autopsy was performed. So far as possible use the terms employed in "Causes of Sickness and Death," United States Census Bureau, 1911. Field workers should study this list. Note directions given in paragraph below entitled "Description of Traits and Causes of Sickness and Death.")

7. Place of death. (Useful in comparison with town and vital records.)

8. If immigrant, date of immigration (steamship and port of entry where possible).

9. Mental and physical condition of each person. (Note paragraph, "Description of Traits and Causes of Sickness and Death.")

10. If married, a description with full name of consort, or of consorts, if married more than once; of the children, and of the consort's parents.

11. Occupations, whenever possible.

12. A general description of the home influences, environment and education.

13. For each family, the sources of information. (Names, addresses and relationships to the individual who is being primarily studied.)

Description of traits and causes of sickness and death.—The field worker naturally directs inquiries primarily toward the specific trait that is being studied (herein called *primary* trait). But the opportunity is utilized to learn of other traits that may be significantly or incidentally associated with the primary trait. In describing traits, the person interviewed is encouraged to talk freely while the field worker records the essential points in the description. In the case of the primary traits too much detail can hardly be obtained, and even in the associated traits she is not to be satisfied with vague terms if the details can be obtained. N. B.—Experience indicates that it is not desirable for the field worker to use a printed form in her interviews.

Such vague terms, to be used only when further details cannot

be obtained, are: *abscess*, without cause of location; *accident*; *decline*, without naming disease; *cancer*, without specifying organ first affected; *congestion*, without naming organ affected; *convulsions*, without details and period of life; *fever; heart trouble* and *heart failure; insanity*, without details (when possible distinguish alcoholic psychoses, progressive or general paralysis, senile dementia, softening of the brain, on the one hand, and such forms as manic-depressive insanity, melancholia, paranoia, dementia præcox, on the other); *kidney trouble*; *lung trouble; marasmus; stomach trouble*. The following data are considered especially valuable as symptoms, and should at the judgment of the field worker be made the subject of inquiry: alcoholism, venereal disease (including gonorrhea and syphilis), sexual immorality, St. Vitus' dance of chorea, and sick headaches.

The term "normal" should be used only to indicate that, in respect to the *primary trait*, the individual is believed on trustworthy evidence to be like most people. Normal is not to be applied to persons simply because nothing is known to the contrary.

Limits to pedigree—How far among collaterals is it desirable to extend the pedigree? This depends on the nature of the primary trait. If, as in the case of most defects, it is due to the absence of a quality essential to normal development then it will be desirable to learn at least of the direct ancestors as far back as possible; the fraternities to which the parents belong; the offspring of all members of such fraternities and the parents of each consort when there are children. Likewise, each of the members of the four grand parental fraternities, their consorts and their children, their children's consorts and the children's children. If the patient has brothers and sisters these together with the patient are studied with the greatest possible care; also their consorts and children, if any.

If the trait is one that never appears in the children unless one parent shows it, then it is desirable to carry back the direct line as far as possible and less attention need be paid to the descendants of certainly normal collaterals beyond what is necessary to establish with certainty the law of inheritance.

4. METHODS OF ANALYSIS

A brief statement of the Mendelian rules of heredity.—So many traits are inherited in accordance with the Mendelian rules that a brief statement of them is appended. But the field worker is warned against being so prejudiced by these rules that her, or his, judgment

is warped. The exact facts are to be sought; their interpretation must come later. So far as possible all statements should be verified. In general a statement may be regarded as verified when made by a second, independent witness.

With this caution in mind the Mendelian rules will be found useful in directing the field worker in her inquiries. First, it is important to disabuse the mind of the popular error that traits are inherited from ancestors. Strictly, traits are not inherited at all; what is inherited is a condition of the reproductive or germ cells which determines the development of the trait—the trait depends on the presence or absence of a *determiner* in the germ cells.

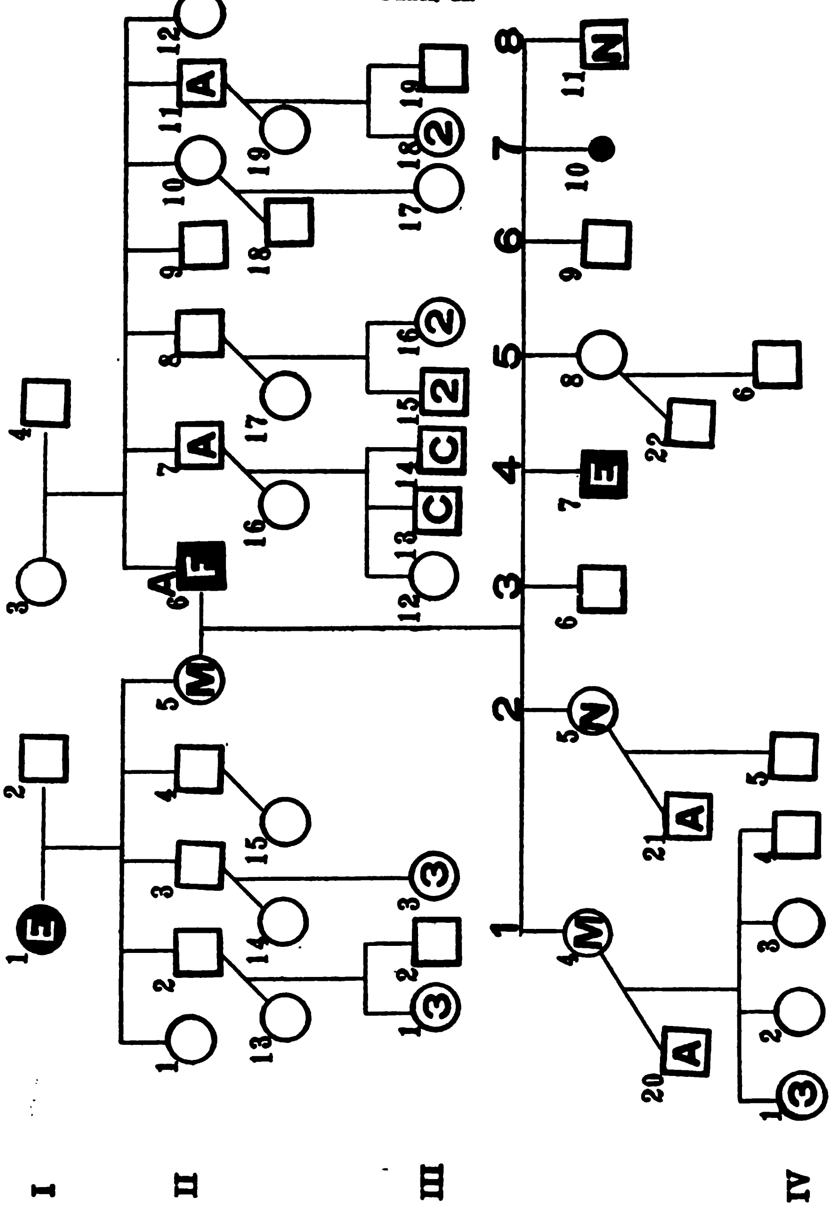
Some defects that the field worker will study, such as albinism and feeble-mindedness, are known as recessive defects, i.e., they are defects due to the absence of the determiner making for normality in respect to these traits. Other defects, such as cataract and brachydactylism, are dominant defects, which means that they are due to the presence of some germinal determiner in addition to all the determiners for normality in respect to these characteristics. Thus, in respect to one character there are three gametic and two somatic types of individuals. Somatically, the individual has or has not the defect; these are the two somatic types. Gametically the germ plasm of the individual may possess alternately germ cells with and without the determiner studied; an individual carrying such a germ plasm is said to be *simplex* and somatically cannot be easily distinguished from a *duplex* individual in which every germ cell possesses the determiner in question. The third gametic type is said to be *nulliplex* in which none of the germ cells possess the determiner in question. There are thus six types of gametic matings in reference to a single character; these types may be expressed as follows:

Type 1. $(D + D) \times (D + D) = 4DD$
Type 2. $(D + D) \times (D + R) = 2DD + 2DR$
Type 3. $(D + D) \times (R + R) = 4DR$
Type 4. $(D + R) \times (D + R) = DD + 2DR + RR$
Type 5. $(D + R) \times (R + R) = 2DR + 2RR$
Type 6. $(R + R) \times (R + R) = 4RR$

D stands for the determiner for the trait studied and R stands for its absence.

The field worker must understand that research, seeking to unravel the laws of inheritance, must work out the gametic nature of each individual studied, hence the necessity of extending the pedigree to all ancestors with collaterals, descendants and consorts of all individ-

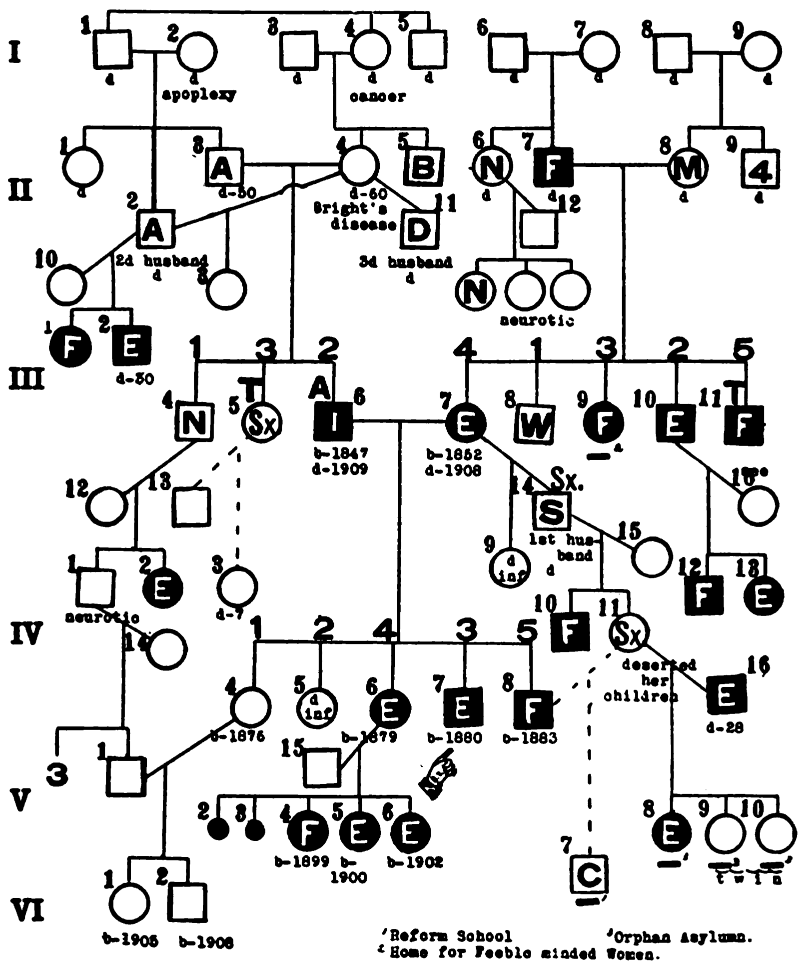
PLATE II.



uals the make-up of whose germ plasm it is desired to understand. For example, by hypothesis, feeble-mindedness is for the most part a recessive trait and the hypothesis must be tested as follows: The

PLATE III.

Hypothetical pedigree, illustrating use of symbols.



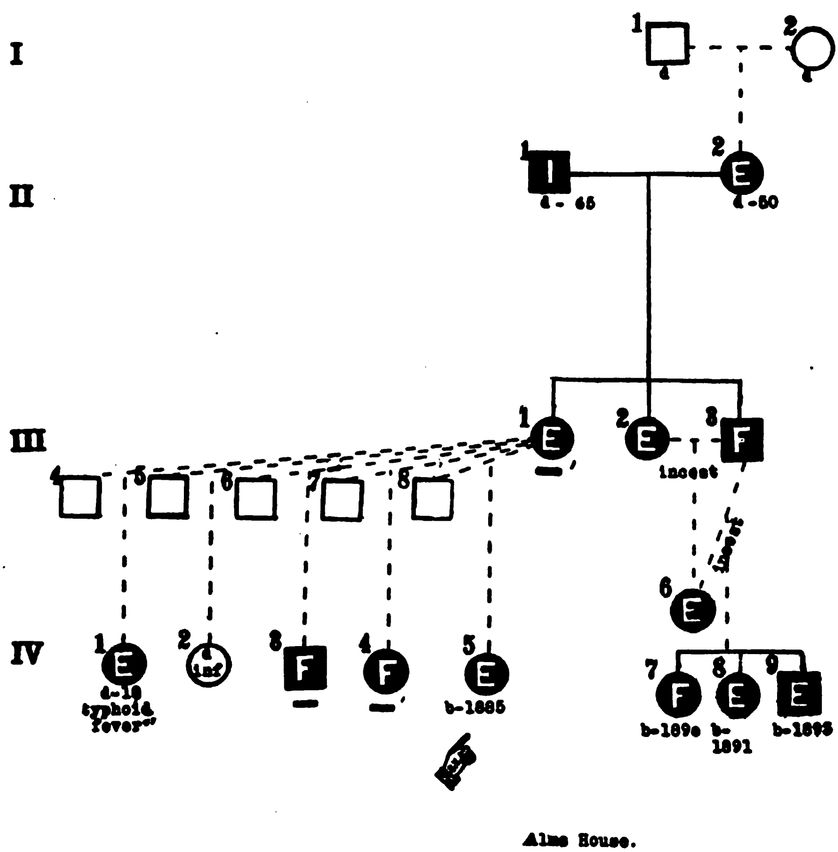
field worker finds a person suffering from feeble-mindedness, a descendant of two normal parents—by hypothesis both of these parents are *simplex*; the field worker must understand that each parent will probably have somewhere in his or her ancestry a feeble-minded

person and it is the business of the field worker to make a special search for such person or persons in the pedigree.

Criticism of an actual pedigree reported by a field worker.—(Plate II.) This study begins with the epileptic boy III—7. The principal thing, of course, is to describe accurately all of the brothers and

PLATE IV.

Hypothetical pedigree, illustrating use of symbols.



sisters of the affected person, they, being produced by the union of the same two germ plasms, will throw light on the make-up of such germ plasm. The pedigree is to be criticised from this standpoint. More information should be got concerning III—6, 8 and 9. The field worker at once notes that the mating II—5 and 6 is the most important one

to be studied, in that this mating produced the fraternity just described. The father, described as feeble-minded, should form the basis of an extended study. It is noted that his parents died at an old age but nothing further is known of either of them. If possible, they should be proven to be either normal or nervously affected. If normal, then it will be a profitable expenditure of time to search the ancestry and complete fraternities of each for affected individuals in order thoroughly to test the hypothesis in this mating. Likewise the mating I—1 and 2 should be studied with a view to determining the nature of I—2; it is apparent that if I—2 is normal all of his five children should also be normal, and if they were so it would not be profitable to spend very much time in tracing further his blood. The fraternities II—1 to 5 and II—6 to 12 should be more thoroughly studied in that a detailed knowledge of each will throw light on the nature of the germ plasm producing II—5 and 6. More should also be known concerning the consort of II—7 and her "blood," inasmuch as this mating was productive of abnormal offspring. The other consorts of the II generation are not so important, if on investigation the offspring prove all to be normal. Likewise the consorts of III are not so important because their children are all very young; however, for study a few years hence it would be highly desirable to have these persons accurately described, and such description should be made if the requisite information can be secured without too great an expenditure of time.

In this pedigree the field worker has charted the males to the right and the females to the left; this should be reversed for the sake of uniformity of practice. Indicate the year of birth on the pedigree only in the case of young children. This pedigree contains few persons marked (N), normal. It is highly desirable that every person studied should be so thoroughly described that he or she can either be safely marked (N) or given a proper mark designating the type of abnormality possessed.

APPENDIX 1

Forms for written Description of the Chart.

A

Name No.

Date

Source of information.

a. name. b. relation to patient. c. address.

The patient and his home.

a. Description of the patient.

b. Neighborhood.—good, fair, bad.
c. Housing.—tenement, separate house, number of rooms used, condition.
d. Home treatment.—good, bad, fair, neglected.
e. Number in the household.— adults, number normal, number defective; children, number normal, number defective; number of boarders.
f. Financial condition.—good, moderate, poor, very poor.
g. Education.—time in school, grade attended, reason for leaving.

A description of the individuals on the chart, covering the points mentioned in the text (pages 6 and 7), is written up under the following headings:

The patient's fraternity.
The patient's father and his fraternity.
The patient's father's parents and their fraternities.
The patient's mother and her fraternity.
The patient's mother's parents and their fraternities.

B

Suggested in the case of extended pedigrees, particularly those made independently of institutions.

General statement relating to locality (exact position, topography, density of population and, in rural localities, adaptability to agriculture), housing, social condition, and origin.

Order of personal descriptions. Begin with earliest generation, describe father, mother and all their children. Take the oldest married child (at left hand end of fraternity, describe his consort and their progeny. Next describe their oldest married child, his or her consort and progeny and so on, to the youngest generation. Then return to the next married sib of the next to the youngest fraternity already described, and give an account of his consort and their children, and so continue, working from left to right until all fraternities have been described. For example, in Plate I the following order is followed: I, 1, 2, 3, II 1, 2, 3, II (2), 7, III 1; II (3), 4, III 2, 3, 4, 5, 6, 7, 8, I 4, 5, II(4) 5, 6

SYNOPSIS OF ABBREVIATIONS ADOPTED

To be used with full face symbols.

a, alcoholic insanity.	p, paranoia.
d, dementia precox.	s, senile dementia.
g, general paralysis of the insane.	
m, manic depressive insanity.	t, traumatic insanity.

PLATE V.

KEY TO HEREDITY CHART.

	Male.	Female.	
			No Data.
Red	E	E	Epileptic.
Black	F	F	Feeble-minded.
Green	I	I	Insane.
Violet	C	C	Criminalistic.

Other letters used in or around the squares or circles are:

- **A** Alcoholic.
- **B** Blind.
- **D** Deaf.
- **M** Migraneous.
- **N** Normal.
- **Ne.** Neurotic.
- **P** Paralytic.
- **Sx.** Sexually immoral.
- **S** Syphilitic.
- **T** Tubercular.
- **W** Wanderer or confirmed runaway.

FIGURES.

Above the line—Order in the line of birth.
Above the square or circle—Individual reference number.
Below the square or circle—Age at time of death or date of birth or death.
In squares or circles—Number of individuals of that sex.

SMALL LETTERS.

b—Born. † or (d) Died or dead.
† (d) inf.—Died in infancy. m—Married.

LINES.

Solid—Connects married individuals and fraternities.
Dotted—Not married or illegitimate.

For display charts.
- Green—Paternal side } of individual under study.
- Red—Maternal side } of individual under study.
- Violet—Connects related charts or individuals on more than one chart.

SYMBOLS.

Shows patient at institution reporting.

Miscarriage or stillbirth.

Institutional care (place under symbol).

To be written on chart.

bd Bright's disease.
ca cancer.
cb childbirth.
ch chorea.
cr cripple.
df deformed.
dp dementia precox.
dt delirium tremens.
dy dropsy.
ec excentricity.
en encephalitis.
go goitre.
gp general paralysis of the insane.
hy hysteria.
id ill-defined organic disease.
kd kidney disease.
la locomotor ataxia.
md manic depressive insanity.
np neuropathic condition.
obs obesity.
pa paranoia.
pn pneumonia.
sh shiftlessness.
sm simple meningitis.
sb softening of the brain.
sco scoliosis.
sd senile dementia.
su suicide.
va varices, varicose veins.
ve vertigo.
x unknown.
? implies doubt.

THE BEHAVIOR IN INHERITANCE OF THE UNIT-LIKE SERIES

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The purpose of this paper is to demonstrate that the neat fitting of the facts with the presence and absence hypothesis in the analysis of biological pedigrees is not, *per se*, sufficient proof of the location of a genetically independent unit. Work looking to the discovery of the laws governing the inheritance of many mental and physical traits in man is progressing rapidly. As a case in point, Dr. Aaron J. Rosanoff and Miss Gertrude L. Cannon, in studying the inheritance of insanity, have collected in the most approved fashion authentic data, have made an analysis, and announced a tentative conclusion, which I shall call Hypothesis I. It is essentially as follows: The neuropathic make-up is a single recessive to normality trait; the specific type of psychosis assumed being determined by some specific stress of life.

Let us proceed by analogy. The factors contributing to the various eye colors in man are well understood, and since their inheritance has been as satisfactorily and as completely worked out as the behavior of any other traits thus far studied, analogy will be made between the method used by Dr. and Mrs. Davenport in determining the behavior of eye colors and that used in studying insanity, in which latter study

the solution of the riddle seemed at hand immediately upon a close fitting of the facts to the presence and absence hypothesis.

Let Hypothesis II also be presented. In this each specific psychosis behaves as a single unit of inheritance. It is not meant to declare that the facts are necessarily with one or the other of these hypotheses, they may indeed lie with some still unstated hypothesis. However, for present purposes it is enough to proceed by analogy with the examination of the sufficiency of the method employed in fitting the facts to Hypothesis I. Inasmuch as the various combinations of the presence and absence of the determiner of a specific character in the germ plasm make possible six classes of matings, the analysis will be taken up one case at a time.

Let N = the germ cell carrying the dominant, normal or greater presence-condition.

Let p = the germ cell carrying the recessive, neuropathic or lesser-presence condition. The binomial expressions represent the gametic make-up of the individuals.

Where discrepancy exists, comparison between the mating in eye color and the corresponding mating in insanity will be made.

CASE I. $N_2 \times N_2$:

4 NN or 100 per cent NN. No objection. Fits any hypothesis.

CASE II. $N_2 \times Np$:

2 NN + 2 Np or 50 per cent N duplex and 50 per cent N simplex. No great objection. Fits both hypotheses perfectly.

If, however, the offspring with the gametic make-up Np when inbred throw several types of psychoses, it argues strongly for Hypothesis I, provided that only one type of psychosis exists in the ancestry—otherwise it supports Hypothesis II. This mating, however, is more fully examined in Case IV, which in fact it becomes.

CASE III. $N_2 \times Np$:

4 Np or 100 per cent N simplex. No great objection. Fits both hypotheses perfectly. The criticism applied to Case II applies with equal force here, since the offspring are of the same somatic and gametic make-up as the Np offspring of that case.

CASE IV. $Np \times Np$:

$N_2 + 2\,Np + p_2$ or 25 per cent N duplex, 50 per cent N simplex, and 25 per cent neuropathic nulliplex.

Objection. Does not permit that the psychoses series might possibly present a case of *oimosism* (*oimos*, a layer or stratum) a group of traits uniformly dominant or recessive and genetically independent forming a single somatic series wherein the upper or members of greater-presence obscure those of less-presence, when both are present (e.g., black, brown, hazel, green, gray, blue, pink eye color in man); nor that the psychoses series might possibly present a case wherein a group of traits uniformly dominant or recessive and genetically independent form a single somatic series wherein one member or group of members is arbitrarily or necessarily not distinguished from other members of the same series.

Comparison with the following specific eye color matings demonstrate the objection to this analysis:

	Eye color	*Neuropathic state.*
Thus, let		
	Br = Brown eye color.	N = Normal State.
	Bl = Blue eye color. (bl)	M = Melancholia. (m)
	Al = Albino eye color. (al)	D = Dementia. (d)

Analogous cases:

Br al × Br bl = $BrBr_2 + Br\ al + Br\ bl + Bl\ al$

The mating (Nd × Nm) would under Hypothesis I be placed in Case IV, i.e., N simplex as to some neuropathic state by N simplex as to some neuropathic states and 25 per cent neuropathic.

All of which demonstrates that Hypothesis I is satisfied perfectly, but does not necessarily preclude Hypothesis II—it rather forces its tenability. At any rate, the fitting to Hypothesis I alone is sufficient for final analysis.

CASE V. Np × p_2:

2 Np + 2 p_2 or 50 per cent N simplex and 50 per cent p nulliplex.

Objection. Analogy = $Br\ al \times Bl\ al + Br\ al + al_2$ or 50 per cent pigmented and 50 per cent unpigmented. The mating (Nd × Md) by Hypothesis I falls under Case V.

Nd × Md = $Nm + Md + Nd + d_2$ or 50 per cent normal simplex as to some neuropathic conditions and 50 per cent neuropathic—apparently two types of psychoses from one, but in truth probably quite different.

Again, perfect conformity to Hypothesis I but conformity to such general type as to suggest that further analysis might demonstrate more specific units of inheritance.

CASE VI. $p_2 \times p_2$:

4 p_2 or 100 per cent neuropathic.

Objection. Analogy Bl al × al_2 = 50 per cent Bl al + 50 per cent al_2 or 100 per cent unpigmented. The mating Md × d_2 = 50 per cent Md + 50 per cent d_2 or 100 per cent neuropathic.

Again, perfect conformity to Hypothesis I which *might* yield to further analysis and finer discrimination.

Only in so far as it pertains to some indefinite neuropathic state is Hypothesis I demonstrated. For practical eugenics, since all hereditary neuropathic states are undesirable, this is sufficient to advise as to the general neuropathic outcome of matings. The conclusion that a general neuropathic weakness is the only thing inherited and that the specific psychosis is determined by some specific stress may or may not be correct, but it is not and cannot be demonstrated by fitting the facts to the mass hypothesis; they must also be fitted to the inheritance of the specific psychoses hypothesis, or even the hypothesis making each measurable factor a unit, before the truth can be arrived at. Since there are many definitely describable types

of psychoses, it is evident that the study of many authentic pedigrees is required for ultimate analysis.

Human eye color, drawing the line of demarcation anywhere in the series and massing the colors on either side, presents perfect Mendelian analysis, but it is not therefore permissible to state that "pigmentation alone is inherited; specific eye color is due to some specific stress." A well supported Mendelian ratio is an indication of Mendelian inheritance. This inheritance may be, first, that of the independent unit, as brachydactylism, or, second, that of a group of uniformly dominant or recessive phases of a series of undistinguished or undistinguishable traits, as the eye color series arbitrarily divided at any point, or, third, that of a portion of a unit, as the red eye of the albino, a feature of general albinism which when studied alone behaves in Mendelian fashion. The unit of inheritance is the thing that is genetically independent; its entity is not dependent upon its size or extent, its strength, its permanence, or its composite or atomic nature.

As evidence of the behavior of units moving *en masse* and as to the possibility of their segregation, note that Dr. Clarence Loeb of St. Louis, in his paper on "Hereditary Blindness," reports 1211 families presenting cases in point. In these families there is a total of 4155 children, out of which number 2523 are affected. He classifies blindness into twelve types, and the striking thing made apparent by either a cursory or careful study of these pedigrees is that it is not some indefinite type of blindness or eye weakness, but is invariably some specific type of eye defect that is transmitted. In a few cases, however, several types of eye defect are present in a single individual from a family containing several blind members; no other member of the family, however, possesses all of the same defects. From this it appears that the genetically independent inheritance unit is some specific defect; that these different defects have come from different inheritance sources. But, of course, only an analysis of the extended pedigrees of such families with several distinct defects will reveal the truth. Dr. Loeb does not detail the inheritance of specific types of cataract, but classes them all under the generic term.

As further evidence that the Mendelian ratio is not necessarily an indication of the genetically independent unit, the accompanying analysis of pedigrees of cataractous families given in the 1909 Report of the Medical Officer of Education to the London County Council is presented. Many family histories of this type have been worked

out, and these are selected almost at random in order to simply show how different analyses give different results. This report tabulates nine families with fifty-one matings and two hundred and eight offspring. The cataracts are of several types, the lamellar type existing with the cataractous members in five families. Attention is called to the fact that the entire group of pedigrees fit very satisfactorily into the general hypothesis that cataract, regardless of type, is a dominant defect. It is further noted that in the five families marked by lamellar cataract this type only appears; in Family III only the coralliform appeared; in Family IV anterior cataract only; in Family V posterior only; in Family VI cataract was congenital; in other cases not so. While these classes are not all mutually exclusive, they are at least definite.

The result of this analysis is to support the general hypothesis, viz., that cataract is a dominant defect, and, further, that each type of cataract behaves as a single unit—which in truth it may be; but the result is not opposed to the view that cataract is a group of similarly behaving units. The whole study suggests that possibly many "units" may in reality be complexes of minute and synchronous elements that are in fact the things that are genetically independent. In this connection it is interesting to note that it is easier to collect and analyze reliable authentic pedigrees of defects that are dominant, since the simplex condition of an individual is marked by an abnormal state; and, further, that defects that are dominant are of less danger to the race. On the other hand, a defect that is recessive, while of less danger to the individual, is of greater danger to the race in that the simplex individual may be somatically normal. Hence the danger of simplex-normal matings unknowingly contaminating the race.

In the analysis of these pedigrees describing the family distribution of cataract, it is noted that in only one case were cataractous children reported from normal by normal matings, although at least one of the normal parents of each mating was invariably extracted from a cataractous family. If the hypothesis is true, there would of course be no exceptions. It may be that one of the persons reported normal was in fact cataractous, or had not yet reached the cataractous age, having come from a cataractous family; this case, however, must be investigated further.

The tabulation of the fitting of the matings to the hypothesis follows:

HYPOTHESIS

The presence of cataract is dominant over its absence. Cataractous individuals are Duplex (D) or Simplex (S), while normal individuals are Nulliplex (N). Based on the evidence of the charted pedigrees.

Incidentally, the inspection of these tables emphasizes the truth that the telling method of handling pedigrees consists not in massing and averaging but in fitting the offspring of each mating to the expectation from the known gametic make-up of the two parents.

Cases of oimosism with little data readily yield the Mendelian ratios to the mass hypothesis, but as in the case of eye color the appearance of a Mendelian ratio only begins the story. The fitting to the more specific hypothesis is one of the steps essential to locating and circumscribing the unit. The functional psychoses series may or may not be a case of *oimosism*. Further analysis is needed.

As this paper is being finished, the January, 1911, *Eugenics Review* is received. It contains an article on "Heredity and Insanity," by Dr. F. W. Mott, pathologist to the London County hospitals, in which he concludes that some types of hereditary insanity are subject to similar inheritance—the rule being, however, for a different type to appear.

If Mendelian fittings are to be followed, Case V must be followed up with extensive authentic pedigrees, for, if there are genetically related groups or stages of psychopathic conditions, two types can *apparently* come from one, although each is independently transmitted.

Summary.

	Number families.	Number matings.	Total Offspring.	Offspring found.			Offspring expected.		
				D	S	N	D	S	N
Lamellar cataract....	5	39	153	0	43	112	0	46.5	108.5
Cataract other than lamellar............	4	12	55	0	18	37	0	19.5	35.5
Total all types...	9	51	208	0	61	149	0	66	144

FAMILY I.—*Lamellar cataract.*

Serial. No.	Matings.	Offspring Found. D	Offspring Found. S	Offspring Found. N	Offspring Expected. D	Offspring Expected. S	Offspring Expected. N
1	S X N		3	2		2.5	2.5
2	S X N		4	1		2.5	2.5
3	N X N			4			4
4	S X N		3	3		3	3
5	N X N			1			1
6	S X N		2	2		2	2
7	S X N			1		0.5	0.5
8	N X N			5			5
9	N X N			5			5
10	N X N			2			2
11	S X N		1			0.5	0.5
12	S X N		1	2		1.5	1.5
13	S X N		4	3		3.5	3.5
14	N X N			1			1
	Total	0	18	32	0	16	34

FAMILY II.—*Lamellar cataract.*

Serial No.	Matings.	Offspring found. D	Offspring found. S	Offspring found. N	Offspring expected. D	Offspring expected. S	Offspring expected. N
1	N X N			3			3
2	S X N		3	1		2	2
3	S X N		2	0		1	1
4	N X N			3			3
5	S X N		2	3		2.5	2.5
6	S X N		3	3		3	3
7	N X N			1			1
8	N X N			3			3
9	N X N			1			1
	Total	0	10	18	0	8.5	19.5

FAMILY III.—*Corralliform cataract.*

Serial No.	Matings.	Offspring found. D	Offspring found. S	Offspring found. N	Offspring expected. D	Offspring expected. S	Offspring expected. N
1	S X N		1	2	0	1.5	1.5

FAMILY IV.—*Anterior polar cataract.*

Serial No.	Matings.	D	S	N	D	S	N
1	S X N		2	6		4	4
2	N X N			1			1
	Total	0	2	7	0	4	5

FAMILY V.—*Posterior polar cataract.*

Serial No.	Matings.	D	S	N	D	S	N
1	N X N		2	4			6
2	S X N		3	2		2.5	2.5
3	N X N			2			2
4	S X N		3			1.5	1.5
5	N X N			1			1
6	S X N		2	6		4	4
7	N X N			6			6
	Total	0	10	21	0	8	23

FAMILY VI.—*Congenital cataract.*

Serial No.	Matings.	D	S	N	D	S	N
1	S X N		6	4		5	5
2	S X N		1	1		1	1
	To al		7	5		6	6
	Grand total (cataracts other than lamellar	0	18	37	0	19.5	35.5

FAMILY VII.—*Lamellar cataract.*

Serial No.	Matings.	Offspring found.			Offspring expected.		
		D	S	N	D	S	N
1	S X N		3	4		3.5	3.5
2	S X N		1	1		1	1
	Total		4	5		4.5	4.5

FAMILY VIII.—*Lamellar cataract.*

Serial No.	Matings.	Offspring found.			Offspring expected.		
		D	S	N	D	S	N
1	S X N	0	2	1	0	1.5	1.5
2	N X N	0	0	5	0	0	5
3	S X N		1	2		1.5	1.5
4	N X N			1			1
5	S X N (Cousins).		5	3		4	4
6	S X N			11		5.5	5.5
7	N X N			12			12
8	N X N			10			10
9	S X N			4		2	2
10	S X N		1	3		2	2
	Total	0	9	52	0	16.5	44.5

FAMILY IX.—*Lamellar cataract.*

Serial No.	Matings.	Offspring found.			Offspring expected.		
		D	S	N	D	S	N
1	N X N........	....	1	4	....	....	5
2	S X N........	....	1	1	....	1	1
	Total........	....	2	5	....	1	6
	Grand Total........	....	43	112	....	46.5	108.5

AN ALGEBRA OF MENDELISM AND ITS APPLICATION TO A MIXED HYBRID POPULATION[a]

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The phenomena of inheritance are described in Punnett's *Mendelism* as follows: "In the majority of plants (and animals) the genesis of a new individual is the result of a process the essential feature of which consists in the union of a female cell, the egg or ovule, with a more minute male cell, the spermatozoon or pollengrain. Such cells, both male and female, are called *gametes*. The cell formed by the fusion of a male with a female gamete is named a *zygote*. This unicellular zygote, by a process of repeated nuclear division, ultimately gives rise to the adult plant or animal with its contained germ-cells. The germ-cells, at first immature, subsequently ripen to form the gametes, thus completing the life cycle. *Since the gametes form the link connecting successive adult generations, the characters peculiar to the latter must be represented in the constitution of the former.*"

"If two gametes uniting each bring in a certain character the resulting zygote is known as a *homozygote* and the individual as *homozygous* or *pure* for that character. A zygote formed by the union of dissimilar gametes is a *heterozygote*, and the individual resulting is *heterozygous*," *not pure* in the character, which was introduced from one side only.

Mendel's great discovery is this, that an individual homozygous in a certain character always transmits that character through its gametes, while an individual impure or heterozygous in a certain character transmits that character in one-half of its gametes, and does not transmit it in the other half. A homozygous individual has

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for instance received the character A from each of its parents; it may then be written as of formula AA for that character. This individual always transmits A in every gamete. Another individual has received the character A from one parent, and an opposite character a from the other parent. The formula of this heterozygous individual is Aa. It transmits A in one-half of its gametes, and a, the opposite character, in the other half.

Such a pair of characters, which alternate with each other in transmission from a heterozygous parent, is called an *allelomorphic pair*. It is found experimentally that such pairs are best explained on a presence and absence hypothesis. In the absence of a certain positive determinant we have a; in its presence A. The heterozygous individual Aa may be said to have received one dose of the determinant for the character A; the homozygote AA has received two doses, one from each parent. It is found very frequently in plants, and with fair frequency in animals, that the individual Aa resembles outwardly the individual AA so closely that the inheritance test, by raising progeny from each, is necessary to show purity or impurity in the character A. In such a case, where one dose of the determinant produces the same observable effect as two doses, it is said that the character A is *dominant* over the opposite character a. Dominance does not necessarily occur; the heterozygote Aa is occasionally in plants, and frequently in animals, intermediate in appearance between AA and aa. This is spoken of as *blending* or *incomplete dominance*.

Mendel's law seems now to have had ample experimental proof. The questions now are not as to the truth of the law in general but with its interpretation and use. How minute, of what kind, may be that thing which we call a unit character? And what is the mechanism of the transmission of the unit character, how is it represented, in the gamete?

If Mendel's law be true, then the possibilities of inheritance can be calculated by the law of chance and the algebra of permutations and combinations. We propose, in the matter to follow, to show the development of such an algebraic method for investigating Mendelian inheritance. The algebraic method possesses advantages in simplicity of presentation and speed of calculation, in flexibility and power of analysis, over the geometric and other methods which we have so far seen.

Consider first that the parents introduce one allelomorphic pair of characters, A and a. The first generation, symbolized by F_1, will be of the formula Aa, and all individuals of this generation will

be alike. Interbreeding the F_1 individuals can give rise to the following combinations, the gametes containing either A or a from either side: AA, Aa, aA, aa; and these combinations should occur with equal frequency. The result may be represented algebraically as: $(A + a)(A + a) = AA + Aa + aA + aa$. The ratio of pure AA to mixed, Aa or aA, to pure aa is 1: 2 : 1. The ratio of individuals in F_2 (second generation) containing one character of the allelomorphic pair to those free of that character is 3: 1. If there is complete dominance of A over a, we will find 3 dominants in F_2 to one recessive (individual pure to aa, complete absence of the dominant character). If dominance is incomplete, there will be three visible classes of individuals in F_2 dominants, blends, and recessives, in ratio of frequency 1:2:1.

Now let the F_2 generation interbreed, that is, breed AA, Aa, aA, aa, each with AA, Aa, aA, aa. Carrying out the complete series of multiplications

$$\left.\begin{array}{r} (A + A), \\ \text{or } (A + a), \\ \text{or } (a + A), \\ \text{or } (a + a), \end{array}\right\} \begin{array}{c} \text{. each} \\ \text{with} \end{array} \left\{\begin{array}{l} (A + A), \\ \text{or } (A + a), \\ \text{or } (a + A), \\ \text{or } (a + a), \end{array}\right.$$

and tabulating the results, the F_3 generation will be found to be 16 AA + 32 (Aa or aA) + 16 aa. For in the left parentheses A can be chosen in 4 ways, to combine with any one of 4 A's on the right, thus making 16 ways of getting AA; similarly there are 16 ways of getting aa; while an A from the left side can be combined with an a from the right in $4 \times 4 = 16$ ways, and an a from the left can be combined with an A from the right in 16 ways making 32 ways in all of getting A and a combined. But in relative frequency 16 AA + 32 (Aa or aA) + 16 aa = AA + 2 (Aa or aA) + aa, the same as in F_2. That is, theoretically *continued breeding will produce in F_3 and succeeding generations no new arrangement of characters and no different frequency of types than occur already in F_2.* This conclusion is general and is highly important, for it makes it unnecessary to breed farther than the second generation, F_2, save to confirm results already obtained.

Consider now the case in which the parents furnish two character pairs A and a, B and b. The F_1 generation, combining both pairs, will be uniformly of formula $AaBb$. The interbreeding of the F_1 individuals, to get the F_2 generation, is represented by $(AA + Aa + aA + aa)$ $(BB + Bb + bB + bb)$. The first parenthesis gives all the possible variations of the character pair A and a which can occur

in F_2, while the second parenthesis similarly cares for B and b. The product of the two parentheses represents all of the possible double combinations of A and a with B and b. Assuming dominance of A over a and B over b, inspection of the function shows the following:

(1). A can be picked in 3 ways from the first parenthesis, B in 3 ways from the second; hence A and B can be had together in $3 \times 3 = 9$ ways, of which the pure double dominant $AABB$ constitutes one.

(2) A can be had without B in 3×1 ways, because there is only one way to choose a factor from the second parenthesis without getting B.

(3) Similarly B can be had without A in 3×1 ways.

(4) A and B can be both left out in $1 \times 1 = 1$ way only.

The visible classes of individuals in F_2 will be four-double dominants, two classes each containing one of the dominants and free of the other, and complete recessives, free of both dominants. The frequency of these various classes will be as derived above 9 : 3 : 3 : 1.

Let the parents furnish three character pairs A and a, B and b, C and c. The F_1 generation will be all alike $AaBbCc$ in formula. The F_2 generation will be found from

$$\begin{aligned} &(AA + Aa + aA + aa) \\ \times &(BB + Bb + bB + bb) \\ \times &(CC + Cc + cC + cc). \end{aligned}$$

The total number of terms resulting from multiplying out will be $4 \times 4 \times 4 = 4^3 = 64$. We can have A, B, and C together in $3 \times 3 \times 3 = 27$ ways, of which the triple pure dominant $AABBCC$ is one. We can have A and B without C in $3 \times 3 \times 1 \times 9$ ways; A and C without B, and B and C without A, likewise in $3 \times 3 \times 1 = 9$ ways. We can have A, B, or C, with the other two dominants left out, each in $3 \times 1 \times 1 = 3$ ways. Lastly, we can leave out A, B, and C in $1 \times 1 \times 1 = 1$ way. The visible classes of individuals occurring in F_2 will be—

A, B, and C—one class with all dominants included,

$\left.\begin{array}{l} A,\ B, \text{ without } C \\ A,\ C, \text{ without } B \\ B,\ C, \text{ without } A \end{array}\right\}$ Three classes each with one dominant left out,

$\left.\begin{array}{l} A \text{ without } B \text{ and } C \\ B \text{ without } A \text{ and } C \\ C \text{ without } A \text{ and } B \end{array}\right\}$ Three classes each with two dominants left out,

A, B, C, all left out — one class with all dominants out.

Total, $1 + 3 + 3 + 1 = 8$ classes, of frequencies respectively 27, 9, 3, 1. Schematically we may represent the result as—

....	9	3	....
27	9	3	1
....	9	3	....

The development of the function for the F_2 generation for any number of character pairs is now evident. The function is

$$
\begin{array}{l}
\quad (AA + Aa + aA + aa) \\
\times\ (BB + Bb + bB + bb) \\
\times\ (CC + Cc + cC + cc) \\
\times\ (DD + Dd + dD + dd) \\
\times\ (E \qquad\qquad\qquad\quad e) \\
\times\ (F \ \text{..................}\ f) \\
\times\ (G \ \text{..................}\ g)
\end{array}
$$

etc., to n parenthesis, one for each character pair entering. The number of terms resulting from the multiplying out of the entire set of parentheses will be 4^n. Unless there be at least 4^n individuals in the F_2 generation, some class must be deficient in numbers from the frequency which it should have by the law of chance. Hence we draw the conclusion to realize experimentally anything like the expected frequency of a class we must have at least 20 to 100 times 4^n individuals in F_2. The number of classes will be 2^n. As we consider the leaving out of, first, one dominant at a time, second, two at a time, etc., we change each time the frequency of the class with the next lower number of dominants, decreasing the frequency in the ratio 3:1. The general formula for n pairs with dominance in each pair using r to represent the number of dominants left out in a given class, is—

Frequency of class. Number of classes.

$$
4^n = \begin{array}{c}\text{(Total num-}\\ \text{ber of terms)}\end{array}
\left\{
\begin{array}{l}
\quad 3^{(n-0)} \text{ times } 1 \\[4pt]
+\ 3^{(n-1)} \text{ times } \dfrac{n}{1} \\[4pt]
+\ 3^{(n-2)} \text{ times } \dfrac{n}{1} \cdot \dfrac{(n-1)}{2} \\[4pt]
+\ 3^{(n-3)} \text{ times } \dfrac{n}{1} \cdot \dfrac{(n-1)}{2} \cdot \dfrac{(n-2)}{3} \\[4pt]
+\ 3^{(n-4)} \text{ times } \dfrac{n(n-1)(n-2)(n-3)}{1 \times 2 \times 3 \times 4} \\[4pt]
+\ 3^{(n-r)} \text{ times } \dfrac{n(n-1)(n-2) \ldots\ldots (n-r+1)}{1 \times 2 \times 3 \times \ldots\ldots r}
\end{array}
\right.
$$

The last is the general term for frequency and number of classes, in case of n pairs with r dominants left out For example, with 8 pairs, 4 ofwhich are left out, the frequency of each class will be $3^{(8-4)} = 3^4 = 81$, as against a total number of terms of $4^8 = 65{,}536$, and the number of ways in which classes can be made by choosing four dominants out of eight $= \dfrac{8 \times 7 \times 5 \times 5}{1 \times 2 \times 3 \times 4} = 70$.

In the above form the usefulness of the scheme is hardly apparent. Thrown into the form of percentage frequency of each class, in relation to total numberof individuals of all classes, the value of the formulas shows up. Assuming first complete dominance in each pair of characters, we can tabulate as follows:

TABLE 1.—*Results in F_2 with complete dominance in every character pair.*

No. of character pairs.	Total No. of classes.	Number of classes and percentage frequency of each class, with number of dominants left in each class of F_2 or any subsequent generation.										
		n-0	n-1	n-2	n-3	n-4	n-5	n-6	n-7	n-8	n-9	n-10
0	1	1 100.00										
1	2	1 75.00	1 25.00									
2	4	1 56.25	2 18.75	1 6.25								
3	8	1 42.19	3 14.06	3 4.69	1 1.56							
4	16	1 31.64	4 10.55	6 3.52	4 1.17	1 0.391						
5	32	1 23.73	5 7.91	10 2.64	10 0.879	5 0.293	1 0.0977					
6	64	1 17.80	6 5.93	15 1.98	20 0.659	15 0.220	6 0.0732	1 0.0244				
7	128	1 13.35	7 4.45	21 1.48	35 0.494	35 0.165	21 0.0549	7 0.0183	1 0.00610			
8	256	1 10.01	8 3.34	28 1.11	56 0.371	70 0.124	56 0.0412	28 0.0137	8 0.00458	1 0.00153		
9	512	1 7.51	9 2.50	36 0.834	84 0.278	126 0.0927	126 0.0309	84 0.0103	36 0.00343	9 0.00114	1 0.000381	
10	1024	1 5.63	10 1.88	45 0.626	120 0.209	210 0.0695	252 0.0232	210 0.00772	120 0.00257	45 0.000858	10 0.000286	1 0.0000954

To make use of this table, an investigator should arrange his material into classes, putting all like individuals into one class together; count the individuals of each class, and compute the percentage frequency of each class in relation to the total number of all individuals.

A comparison with the table of the number of classes and their percentage distributions should place at once his material as containing a certain number of character pairs. Further, it will show the number of dominants in each of his classes, and so help to a rapid

selection of the members of each character pair, the dominant and recessive parts.

Complete dominance may be lacking in some one character pair. Let this pair be A and a. Then instead of AA looking like Aa and aA, there will be obvious differences. Every class containing the character A will be split into two parts, one-third of the class being AA, pure in A, while two-thirds will be blends or heterozygotes. The apparent number of classes present will be increased from 2^n to $2^{(n+1)} - n)$. Take, for illustration, the case of three character pairs. If dominance is complete in A, B and C we have the distribution in per cents to classes:

....	14.06	4.69	....
42.19	14.06	4.69	1.56
....	14.06	4.69	....

With dominance incomplete in A, the new distribution is —

....	4.69	1.56	....
14.06	9.37	3.13	....
28.13	4.69	1.56	....
....	9.37	3.13	1.56
....	14.06	4.69	....

or, as it would appear —

....	....	....	4.69	....	....
....	14.06	9.37	....	3.13	1.56
28.13	....	....	4.69	....	1.56
....	14.06	9.37	4.69	3.13	....
....	....	....	....	....	1.56

It is obvious that if there are enough individuals present to make the percentages come out fairly accurately, say 100×4^n individuals or more, this altered quantity will not be confused with the next larger number of character pairs, in this case 4. If, however, the number of individuals is not large enough to make the percentages accurate, the observer could not tell whether there was incomplete dominance in one of three pairs, or a case of four pairs with some classes imperfectly filled out and others missing. Some other criterion of judgment would have to be found.

If there is incomplete dominance in *two* pairs of characters every class of the table will be cut into twice, by a repetition of the same process as was used in the illustration above. The dividing ratios will be where both A and B are present, $\frac{1}{3} \times \frac{1}{3}$, $\frac{1}{3} \times \frac{2}{3}$, $\frac{2}{3} \times \frac{1}{3}$, $\frac{2}{3} \times \frac{2}{3}$; where

either is present without the other, $\frac{1}{3}$ and $\frac{2}{3}$ as before, and where both are absent, there will be no disturbance. The result, if worked out, would be too complicated for practical use.

A study of Table 1, especially in the lines where the number of character pairs exceeds five, and consideration of the additional complicating effect of lack of complete dominance in one or more character pairs, will make evident beyond need of words why biologists have been slow to realize the importance and general applicability of the Mendelian laws of inheritance. The trouble is not that the law does not work, but that its workings are frequently so complicated as to be obscure and unrecognizable. If it were not for the fact that each character pair works out its destiny independently of the others, the law could never have been discovered or demonstrated.

This method of analysis may be more theoretical than practical, but there are cases to which it may be applied with convenience. To illustrate, let us consider a population of hybrid plants, peas, for example, which have been carefully studied genetically and in which there seem to be well defined unit characters. Suppose we analyze this population minutely by carefully studying every plant in it. There may be found eight distinct visible types, indicating as can be seen by the table that it is probably composed of three allelomorphs.

We analyze these eight classes still further, noting the frequency of each and its genetic composition. We may find one class which comprises about 42 per cent of the population. Referring to our table under three pairs of characters, we find that there is one class comprising 42.19 per cent of the total population which is composed of all dominant unit characters. The number of dominants in this class being $N - 0$, where $N =$ number of allelomorphs.

We should expect to find on our theoretical hybrid population three other classes each comprising about 14 per cent of the entire population. These classes would contain $N - 1$ or 2 dominants and one recessive in each class. Similarly, we should expect to find three classes each containing 4.69 per cent of the total number and consisting of one dominant ($N - 2$) and two recessives each. The class containing all recessives would comprise theoretically 1.56 per cent of the population.

This table is suggestive at least. It indicates to us the enormous number of different classes it is possible to have when as many as 8 or 10 allelomorphs are concerned. And is it not possible and even probable that as many allelomorphs as this are concerned in the production of many hybrid populations?

If 10 allelomorphs are represented, it will take theoretically 16,777,-216 (4^{10}, see table, page 317) individuals in the F_2 generation in order to have at least one pure individual to a class. Lock has found as many as 18 distinct heritable characters in peas, so that the 10 assumed above is not out of reason.

If the population which we have been studying are not F_2 hybrids, the above table and percentage will not apply except in regard to the number of visible classes. The latter will hold good for the second or any later generation.

Castle[b] has made use of this method of reasoning, with rabbits and guinea-pigs. He says:

> The facts briefly stated are now before us. We can distinguish among the second-generation gray rabbits, thirty-two different kinds, all looking alike but all breeding differently. Out of this apparent chaos, the Mendelian theory of unit characters brings law and order; no other explanation has been offered which makes anything but chaos out of the situation. The number of distinguishable classes, thirty-two, shows that five independently variable characters are involved; the proportions in which the several sorts of young are produced by each class of gray parents confirms this conclusion. If the number of independent unit characters were one greater, as it is in guinea-pigs, the total number of classes of parents would be doubled to sixty-four; if it were one less, the number of classes of parents would be reduced one-half, to sixteen.

[b] Castle, W. E.: The Behavior of Unit Characters in Heredity. *Fifty Years of Darwinism*, p. 153.

VOLUME VIII

Report of the Eighth Annual Meeting held at Washington, D. C. in affiliation with the American Association for the Advancement of Science, December 28, 29, and 30, 1911, and for the year ending December 31, 1911.

Pages 321 to 580

PROCEEDINGS OF THE MEETING OF THE AMERICAN BREEDERS ASSOCIATION, HELD IN WASHINGTON, D. C., DECEMBER 28, 29, 30, 1911

SECRETARY'S REPORT

The Eighth Annual Meeting of the Association was held in Washinton, D. C., in affiliation with the American Association for the Advancement of Science. Section and general meetings were well attended and on the whole this meeting may be regarded as one of the most successful ever held by the Association. The officers of the Law College of the Washington University generously turned over to our use two small rooms in which the sectional meetings were held, and an assembly hall for holding the general sessions.

The *American Breeders Magazine* is now in its third year. It has enjoyed the continued favor of the public and the members of the Association, and practically no criticisms have reached the editors of the *Magazine*. On the other hand, there has been considerable favorable comment. In order to fill its place and to work out its full purpose, funds should be made available to place the *Magazine* upon a larger basis. The field which it covers justifies a monthly publication of more pages.

The membership of the Association has grown slowly but steadily. There are 1225 actual paid up members and 244 members who are delinquent one year and 210 members who are delinquent two years. The life membership has grown to 194 members, an increase of 59 over last year.

The following motions and resolutions were passed:

That Dr. William Saunders of Ottawa, Canada, and Mr. T. V. Munson, Denison, Texas, be elected honorary life members.

That each retiring President and the Chairmen of the three sections be each expected to present an annual address upon relinquishing the Chair to his successor.

That the Secretaries be authorized to secure committees among members at educational centers through whom a canvass shall be made for members, and where practicable to form clubs and associations.

That the Animal Section of the American Breeders Association approves the so-called Circuit Coöperation System of breeding domestic animals, under

which the Federal and State Governments provide scientific guidance and assistance to coöperating groups of breeders in the production of superior sub-breeds and breeds of animals.

That the American Breeders Association authorize its Executive Council to take action adhering to the International Commisssion of Agriculture and to pay annual dues.

That the American Breeders Association authorize its Executive Council to make this Association a member of the proposed Federation of Peaceful Societies of the United States.

That the American Breeders Association approves the proposition to change the National Farmers Congress into a federation with delegates from all societies and institutions which are national and state in scope under the name American Country Life Federation.

That the Secretary be instructed to write to Professor Spillman and express to him the sympathy of the Association in his illness and the regret of the membership of the Association that he was unable to attend its meetings.

That the Secretary be instructed to express to the authorities of the law college of George Washington University our appreciation of their kindness and courtesy in furnishing rooms for the meetings of the Association.

That we desire to express again to our Secretary, Hon. W. M. Hays, our sincere thanks in appreciation of the very effective service he has rendered the Association during the past year. His loyalty and untiring service in behalf of the Association we consider worthy of the highest commendation.

That the thanks of the American Breeders Association are due to the American Association for the Advancement of Science for the cordial spirit with which our Association was recognized in the affiliation of scientific societies constituting the A. A. A. S.

The following resolutions were recommended for passage by the Eugenics Section, and were passed in general session:

That the Eugenics Section organize a permanent committee on immigration, with authority to cöoperate with similar committees of other organizations in securing laws which will be more effective in securing emigrants which bring good health and only normal and superior heredity to this country.

That the Eugenics Section request the Association to appoint a committee to report on the possibilities of securing data and useful eugenics legislation through the United States Census Bureau, the Bureau of Health and other societies and institutions.

The officers chosen for the year 1912 were as follows:

President, HON. JAMES WILSON; Vice-President, H. J. WATERS; Secretary-Treasurer, W. M. HAYS; Editorial Secretary, GEORGE W. KNORR; Chairman Plant Section, DR. GEORGE H. SHULL; Vice-chairman, PROF. W. T. MACOUN; Secretary, H. J. WEBBER; Chairman Animal Section, DR. RAYMOND PEARL; Vice-Chairman, E. N. WENTWORTH; Secretary, H. W. MUMFORD; Chairman Eugenics Section, DR. E. E. SOUTHARD; Vice-Chairman, DR. H. H. GODDARD; Secretary, DR. C. B. DAVENPORT.

The Secretary of the Eugenics Section reported appointments in the following committees, several new committees having been added since last year:

COMMITTEE ON HEREDITY OF THE FEEBLE-MINDED—A. C. Rogers, Chairman; H. H. Goddard, Vineland, N. J., Secretary; H. H. Donaldson, Philadelphia, Pa; Walter E. Fernald, Waverly, Mass.; J. M. Murdock, Polk, Pa.

COMMITTEE ON HEREDITY OF INSANITY—Adolf Meyer, Chairman; E. E. Southard, Harvard Medical School, Boston, Mass., Secretary; August Hoch, Wards Island, N. Y.; F. A. Woods, Boston, Mass.; A. J. Rosanoff, Kings Park, N. Y.

COMMITTEE ON HEREDITY OF EPILEPSY—W. N. Bullard, Chairman; Everett Flood, Palmer, Mass., Secretary; J. F. Munson, E. E. Southard, D. F. Weeks.

COMMITTEE ON HEREDITY OF CRIMINALITY—C. R. Henderson, Chairman; M. G. Schlapp, Cornell Medical School, New York City, Secretary; W. M. Carmalt, William Healy.

COMMITTEE ON HEREDITY OF DEAFMUTISM—Alexander Graham Bell, Chairman.

COMMITTEE ON HEREDITARY EYE DEFECTS—Brown Pusey, Chicago, Secretary; E. E. Allen, Boston, Mass.; Clarence Loeb, St. Louis; E. Nettleship, Hindhead, Eng.; W. C. Posey, Philadelphia; J. E. Weeks, New York; F. H. Verhoef, Boston.

COMMITTEE ON IMMIGRATION—Prescott F. Hall, Secretary, Boston, Mass.; Franz Boas, New York; A. E. Cance, Amherst, Mass.; James A. Field, Chicago, Ill.; R. DeC. Ward, Cambridge, Mass.

COMMITTEE ON STERILIZATION—Bleecker van Wagenen, Chairman; H. H. Laughlin, Secretary; W. M. Carmalt, New Haven, Conn.; Everett Flood, Palmer, Mass.

COMMITTEE ON GENEALOGY—Clarence I. Brown, F. H. Giddings, W. S. Mills, Aaron F. Randall, P. L. Ricker.

COMMITTEE ON INHERITANCE OF MENTAL TRAITS—Madison Bentley, E. L. Thorndike, Robert M. Yerkes, Harvard University, Secretary.

The following is the audit of the Secretary's books for the period stated below:

TO THE COUNCIL OF THE AMERICAN BREEDERS ASSOCIATION.

Gentlemen: Your Committee appointed to audit the Secretary's accounts for the periods December 1, 1909, to December 31, 1910, and January 1, 1911, to December 31, 1911, finds that the additions balance and that according to the Secretary's books the accounts are correctly summarized in the financial report of the Secretary.

The Committee finds that all expenditures are supported by receipts except some miscellaneous items, chiefly for postage and express, amounting to $39.94, in 1910, and $3.75 in 1911.

The records show that the Association owns stocks and bonds of par value of $3,100.

H. F. ROBERTS,
H. H. LOVE,
W. W. STOCKBERGER.
Auditing Committee.

Report of the Secretary, 1911:

During the period beginning January 1, 1911, and ending December 31, 1911, the following receipts and disbursements were recorded in the books of the Secretary:

RECEIPTS

Balance on hand from last report		$458.30	
Annual	$278.34		
Life	179.96		
Annual dues, sale of books, magazines, etc		2,495.40	
Life dues		702.00	
Dividends from investment		66.00	
Transferred from N. H. Gentry, former Treasurer		2,418.33	
Life	$1,603.00		
Annual	815.33		
Subscription to Promotion Fund from W. M Hays		100.00	
Total			$6,240.03

EXPENDITURES

Printing, copyrights, etc	$2,107.60	
Postage	442.58	
Stationery and incidental expenses	70.56	
Traveling expenses	75.80	
Labor and clerical serices	446.24	
Salary of Editor	299.00	
Surplus annual dues and proceeds from sales of publications, transferred to Treasurer N. H. Gentry	275.00	
Life dues transferred to Treasurer N. H. Gentry	179.96	
Purchase of stock of Riggs Realty Co	2,093.61	
Balance on hand December 31, 1911, *Life*	211.39	
Annual	38.29	
Total		$6,240.03

STOCKS AND BONDS OWNED BY THE ASSOCIATION.

Five shares permanent (non-withdrawable) stock of par value of $100 each of the Ohio Mutual Savings and Loan Company (Cert. No. 611, issued at Cleveland, Ohio, July 21, 1908).

Six shares preferred capital stock of par value of $100.00 each of the Local Telephone Company (Cert. No. 1111, issued at Bellevue ,Ohio, July 20, 1908).

Two 5 per cent first mortgage bonds Nos. 253 and 257 of the Riggs Realty Company, par value $1,000 each.

THE TEACHING OF GENETICS

C. I. Lewis

Corvallis, Ore.

During the past few years the teaching of agriculture has gone through many evolutions and differentiations. A few years ago such branches as horticulture and agronomy gave relatively but few courses where they are now offering in some cases as high as forty separate courses. Plant breeding has not as yet developed to this extent. However, there is great interest taken by our students in genetics and undoubtedly in the next few years we are bound to see many changes in this branch of agriculture. At the present time in most agricultural colleges but limited time is given to this work and the reason is obvious. The first function of the college should be to give its students a broad foundation. Professional training should be a secondary consideration. Under such conditions we find it impossible to give the amount of time for the teaching of genetics that would be desirable to give to students in this valuable line of agriculture. My own experience has led me to believe that the proper handling of this work would be to attempt to give simply good foundation work to the undergraduate and encourage the student who wishes to specialize in breeding to take up graduate study. In several instances my results have been unsatisfactory where I have attempted to give very much of this work before the student had the proper agricultural training. I believe that much of our ground work in plant breeding can be greatly improved. I feel that often we waste too much time on the discussion of theories. Perhaps not enough time was given to the application of these theories to agricultural research. I find that the students often are unable to obtain a clear conception of the true field of plant breeding. On the one hand they may consider it to be simply a study of a whole lot of confusing theories; on the other hand they seem to get an idea that all they have to do after completing the work is to cross plants and that plant breeding is a very easy process and will quickly lead down a golden path. Undoubtedly the popular writings on plant breeding have done a good deal to unsettle our agricultural students. Again there is a confusion in the student's mind concerning animal-

breeding and plant-breeding. While the principles are the same the application is as a rule different. We might come to the conclusion at this time that the teacher is to blame for this condition of the student's mind, but when we consider that there is not sufficient time that can be devoted to this work and that also often the teacher has to handle many other subjects than genetics, we can readily see where the trouble really lies. I believe the student should first be given some good foundation work. This might be given in a department like botany, in various departments like horticulture, or agronomy, or in a separate department of plant breeding. I believe that if a case-book could be devised similar to the book used in law schools, that results would be more satisfactory. I would suggest the choosing of special chapters from the various works on plant breeding that can be bound together in a case-book to give the students a clear idea of the various theories and the basic principles of plant breeding. If such a course were adopted, I believe the students would often have a clearer conception of these theories and much time that is devoted to the work could be used to better advantage along other lines of plant-breeding. To supplement this case-book we need at the present time text-books and reference books entirely different than those that are now available. Many of the present books are too elementary on the one hand, or too complex and drawn out on the other. With a case-book and improved text-books and a few good lectures, I believe our students can be given the proper foundation. If possible I would try to have two courses for the undergraduate, one junior year and one senior year and these courses should naturally interweave. I would attempt to give the student all foundation work in the junior year and for the senior year work, I would give him a great deal of field, laboratory and green' ouse practice. He should get in contact with plants and if it is possible for him to work individually with some simple problem it would be a great advantage, but very little work of true experimental or research nature can be attempted, however, before our student is a graduate. Several years of hard work in which the student is studying genetics should be necessary to develop plant-breeders who would be thoroughly equipped to take up research and experimental work in this profession. In order to handle the graduate work efficiently we should have ample greenhouse space, plenty of outdoor material and should have experimental and research problems in progress with which the student may keep in touch. I feel that in the next few years plant-breeding is going to go through the same differentiations that has

developed in most of our agricultural branches and in a short time we will have courses and experts along specialized lines. Whether or not, however, much of this work can be taken up by the undergraduate is questionable, as I feel that in many cases students are specializing before they have a sufficient foundation knowledge of agriculture.

[Presented by Committee on Pedagogics of Breeding.]

GENETICS IN THE COLLEGE CURRICULUM

A. T. WIANCKO

Lafayette, Indiana

The world-wide interest that has been awakened during the last few years in the improvement of living organisms through important discoveries of laws and principles in inheritance and transmission of characters has made genetics an important subject of study and investigation among scientific and practical workers in plant and animal improvement. Much exact information has been gathered and so much has been learned concerning the practical application of the laws of breeding that the subject is now pressing for a place among the subjects taught in many of the higher institutions of learning. In the agricultural colleges, in particular, the subject is of such vast importance that much thought is being given to the development of courses of instruction that shall embody at least the principles and practices which should be employed by every practical worker in plant or animal improvement. Whether the student is primarily interested in agronomy, animal husbandry, dairying or horticulture, there is much that he should know in the realm of genetics before he can hope to meet with any important degree of success.

The practical value of the subject in the equipment of the agricultural college graduate is now established without question and it remains only to work out the best methods of aiding him to acquire a working knowledge of it. In what part of the course, how, and to what extent it should be taught, are questions of considerable importance, and must be given due consideration. To teach the subject exhaustively in the ordinary four-year course in agriculture is obviously impossible owing to the large number of other subjects that must be included. For the man who is fitting himself to become a practical farmer, only a limited amount of time can be given to the subject

during the four-year course leading to the bachelor's degree. For the man who is fitting himself for experiment station or college work dealing with plant or animal life, some special courses in genetics might be arranged but even here, it will have to be at the expense of fundamental courses in biology or chemistry.

As chairman of the catalogue committe on School of Agriculture courses of instruction, the writer has for a number of years given considerable thought to this question. At the present time in Purdue University we are giving one course in the principles of breeding, of three lecture and recitation hours per week throughout one semester, which is required of all juniors. This course is intended to acquaint the student with the fundamental principles of the subject and their application. In certain of the specialized courses for students intending to go into experiment station or college work this course is supplemented in the senior year with further instruction in the methods of breeding in the line along which they are specializing. Further than this we feel we cannot go in undergraduate work under present conditions. Bearing in mind that the undergraduate student should lay a broad foundation to build upon, we are of the opinion that further specialized study in this field, as well as in several others, should be deferred until later and may well occupy the time given to M. S. and Ph.D. degree work.

[Presented by Committee on Pedagogics of Breeding.]

THE RELATION OF SEED EAR CHARACTERS TO EARLINESS IN CORN[a]

H. H. LOVE

Ithaca, N. Y.

For some time the Department of Plant Breeding of Cornell University has been breeding corn to increase earliness and yield. During the progress of the work it seemed desirable to learn whether there were any visible seed ear characters which may be correlated with either yield or earliness. That is, are there any ear characters which indicate high yield or early maturity? The correlation of some of these seed ear characters with yield per stalk was determined and results presented in the last report of this association (vol. vii, *A. B. A.*) It is therefore, the plan of this paper to deal with the question of earliness.

[a] Paper No. 29, Department of Plant-Breeding, Cornell University, Ithaca, New York.

The degree of earliness was determined in the following manner. The corn was planted by the ear-to-ear method and at the time of husking each row was husked separately and the ears sorted into two piles, ripe and unripe. With a little practice one can make this distinction very easily. The corn is husked earlier than that in neighboring fields in order to get a better comparison between the ripe and unripe ears. After the corn is sorted into piles the number of ears in each pile is counted and the percentage of earliness determined. This is done as follows.

Suppose, for example, the ripe pile contained 66 ears and the unripe pile 44 ears, then the total number of ears for the row is 110 and 66 is 60 per cent of the whole number, therefore, the percentage of ripe ears, or percentage of maturity, is 60.

The following data has been obtained from a breeding plot of Funk's Ninety Day corn and represents three years work. The number of ears used (100) is of necessity small, yet when the work is carried over three years, it indicates what we may expect, although it does not prove it absolutely.

The work was designed to answer two questions which are:

1. Do the smaller ears give corn which is earlier than large ears?
2. As the corn becomes earlier do the ears necessarily become smaller?

To obtain some light on these questions the following characters were studied for the seed ears: length of ear, number of rows, weight of cob, per cent of grain on the ear and circumference of ear. Each of these characters was correlated with the percentage of maturity. This was done by making a correlation table for each character in question, using the character to be studied as subject and the percentage of maturity as relative in each case.

To illustrate this more fully one of the correlation tables, that for number of rows and maturity for 1909 will be given. (See table 1.) Here the number of rows is used as subject and the percentage of maturity as relative. For example, there were two ears having 16 rows and a percentage of maturity ranging between 15 and 20. The coefficients of correlation were determined by the well known biometrical methods, using the following formula for the coefficient of corre-

$$r = \left(\frac{\Sigma D_1 D_2}{n} - C_1 C_2\right) \frac{1}{\sigma_1 \sigma_2}$$

lation, in which D_1, D_2 are deviations from our guesses at the mean instead of deviations from the mean itself; and C_1, C_2 are the corrections for the guesses at the mean; n, the number of individuals, and

σ_1, and σ_2, the standard deviations of the subject and relative classes respectively.

The following table gives the results for the three years.

TABLE 1—*Correlation between number of rows and percentage maturity for Funk's Ninety Day corn 1909.*

[r = 0.008 ± 0.070]

Number of rows	Percentage maturity 0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	
16			1	2		4	3	6	1				1			1	19
18	1		3	3	2	5	3	2	5	3		3	2	1			33
20		1	1	1	7	4	5	3	3	2	4	2					33
22			1		1	1		1		1			2				7
24							1										1
26							1										1
	1	1	6	6	10	14	13	12	9	6	4	5	5	1	0	1	94

Correlation of seed ear characters with maturity in corn.

Character	1909	1910	1911
Length of ear and maturity	−0.161 ± 0.066	0.092. ± 0.067	0.059 ± 0.067
Number of rows and maturity	0.008 ± 0.070	−0.059 ± 0.067	−0.164 ± 0.066
Ear weight and maturity	0.046 ± 0.067	0.104 ± 0.067	0.012 ± 0.067
Cob weight and maturity	−0.151 ± 0.066	0.126 ± 0.066	−0.190 ± 0.065
Per cent grain on ear and maturity	0.170 ± 0.066	−0.071 ± 0.067	0.249 ± 0.063
Ear circumference and maturity	0.152 ± 0.066	−0.042 ± 0.067	−0.129 ± 0.066

It is observed from this table that the coefficients of correlation for length of ear and maturity for the three years are -0.161 ± 0.066, 0.092 ± 0.067, and 0.059 ± 0.067. The first year there was obtained a negative coefficient, while for the two other years the coefficients were positive and not large enough to be of any significance. In one case the correlation coefficient is less than its probable error.

It is apparent from this data that the length of the seed ear makes practically no difference in the maturity. The long ears produce just as early corn as do the short ears.

From other tests§ it has been shown that in a mixed population in corn, the long seed ears tend to reproduce longer ears than do the short seed ears. If this be generally true, then one might expect that should

b Williams, C. G., Bulletin 212, Ohio Agr. Exp. Sta.

the shorter seed ears produce earlier corn than the longer ones, in breeding for earliness, the ears would become shorter and the yield therefore, would decrease. This is not the case, however, for no earlier corn is produced from one kind of an ear than from another.

It was thought that possibly the number of rows of kernels might have an effect on maturity in that as the number or rows increased the kernel would become smaller and therefore, the ear would dry out more quickly. The coefficient of correlation, however, for the three years shows two negative coefficients and one positive. The positive one is 0.008 ± 0.070, practically zero, while the negative coefficients of −0.059 ± 0.067 and − 0.164 ± 0.066, are very small, only the second one being larger than its probable error, and this a little more than twice as much. It is evident that it makes no difference as to earliness whether an ear with 16 rows or one with 20 or 22 rows is planted.

The relation of weight of seed ear to maturity is shown by the correlation coefficients of 0.046 ± 0.067, 0.104 ± 0.067, and 0.012 ± 0.067, for the three years. In other words, there is no effect produced in the earliness by planting either small or large ears. This is a very interesting point since it indicates that breeding for earliness does not necessarily mean that the ears will become smaller.

Notes were taken on the weight of cob to learn whether the size of cob had any influence on the earliness of the offspring. It was thought that possibly an ear with a small cob would produce earlier corn than ears with large cobs. The first years results gave some indication that this might be true since, as the weight of cob increased the earliness decreased. The correlation this year was − 0.151 ± 0.066. The second year, however, the result was different, the correlation coefficient being 0.126 ± 0.066. This coefficient being positive shows that as the size of the cob increased the earliness also increased. The third year gave a negative coefficient of − 0.190 ± 0.065 which shows that as the cob increases in size the earliness decreases. It is apparent that this character, size of cob, has little influence on the maturity, since the results one year may be negative and another positive.

The per cent of grain on the seed ear was determined in the usual way which is to weigh the ear then shell the corn and weigh it, and from these results calculate the per cent of grain. An ear having a high weight of grain in proportion to its cob, would have a high per cent of grain. It is rather interesting to note the correlation coefficient obtained when this character is correlated with earliness. The

coefficients of the three years are 0.170 ± 0.066, − 0.071 ± 0.067 and 0.249 ± 0.063. Thus we see that for two years, the first and third, the correlation coefficients are positive, while for the second a negative coefficient is obtained. The correlation coefficient for the third year may be slightly significant and if the results of all three years had been positive it might indicate that the ears having a high per cent of grain may have some influence on the offspring. However, such a conclusion, with the results at hand, is not justified.

The circumference of the ear was taken to learn whether slender ears would produce any earlier offspring than the thicker ears. The first year a positive correlation coefficient of 0.152 ± 0.066 was obtained, which would indicate to a slight degree that the thicker ears gave earlier corn. The results for the next two years, however, were negative. For the second year the value of the correlation coefficient is 0.042 ± 0.067, which is less than its probable error and for the third year, it is − 0.129 ± 0.066, which is hardly significant.

While the foregoing results are not conclusive owing to the lack of numbers, yet since they cover three years work they certainly are suggestive of the results one may expect. As one reviews the results it is apparent that no character showing a high correlation with maturity stands out. Therefore, it seems impossible by any of the characters mentioned above, to pick out ears which will give an early maturing row and that the only way of determining the question is to plant the different ears and then make the selection of the early rows from the field. With this in mind and knowing by actual tests that the earliness of this variety has been increased, it seems possible to select corn for earliness and still maintain the size of ears and other desirable qualities.

In conclusion, then, it may be stated in answer to the two questions proposed above, that smaller ears do not give earlier corn and that as the corn becomes earlier the ears do not necessarily decrease in size, provided one does not unconsciously select small ears for seed. When comparison is made between the length of ears planted in 1909 and 1911, there is so little difference that we are not justified in stating that the ear is becoming shorter. The same comparison of number of rows and weight of ear between the seed ears for the two years leads us to the same conclusion, that there is no visible effect of diminishing the size of ear as the earliness increases.

PRODUCTIVITY OF SEED CORN AS INFLUENCED BY FACTORS OTHER THAN HEREDITY

C. P. Hartley

Washington, D. C.

The prospects for valuable results both practical and scientific from corn breeding are today very much brighter than ever before. The several disappointments we have sustained through lack of reliable methods, fancy-point-breeding, etc., have but strengthened us.

The prospects are much brighter than ever before:

First, because we have learned that we know very little. We have touched upon great problems failing to grasp their breadth. Our treatment of these great problems has been too narrow and our conclusions insufficiently proven because of defective plans and systems.

Second, because appreciating the weakness of past efforts we are planning for great and valuable victories and are making progress with our planning.

The preliminary tests of some of these plans and methods are brightening the prospects for true progress.

Some ten years testing of methods of corn breeding, planned with care like those of the Ohio and Illinois State Experiment Stations, has given us some facts of great value. This work has demonstrated that in productivity and in composition, one season's corn crop influences the crop of the next season. It has done even more, it has demonstrated the necessity of planning well for corn improvement work—a task as difficult, as intricate, and as remunerative if successfully accomplished, as any ever undertaken. We are improving our methods, but not thoroughly or elaborately enough considering the immense profit that is certain to follow a general increase of the acre yield of corn.

Progress depends upon an adequate foundation of facts. Soil and plant experimenters are agreed that a good foundation and a reliable measure of progress necessitate an improvement and standardization of test plat methods.

A hill system of testing comparative productivity, originated by Mr. Curtis H. Kyle and elaborated by other members of the Office of Corn Investigations of the Bureau of Plant Industry, is a valuable step in advance. By this method more reliable results are being

obtained. Since, in this system, each perfect hill of corn forms a separate test in which the seed to be tested grows under identical conditions with the standard of comparison, an acre so planted affords about 3500 separate tests. In accordance with the requirements of the experiment, this large number of tests can be studied individually or in groups taken by corn rows across the field. Each row thus comprises a long narrow experimental plat, consisting of as many separate tests as a row contains hills.

The employment of this method during the past three years is greatly assisting in attributing yield variations to their proper causes and is proving that as students of heredity we are in many cases "straining at gnats and swallowing camels."

Some results of field tests will be stated to show that as students of heredity we are too prone to attribute to heredity, effects due to other causes. More accurate descriptions of varieties and the retention of samples for future indentification are valuable suggestions, but even these precautions would not prevent productivity due to seed preservation or to adaptation being attributed to heredity.

To illustrate this point: During different seasons and with different varieties, various lots of seed, each divided into halves, one half cribbed and the other half well preserved, have given 0 per cent, 3 per cent, 5 per cent, 11 per cent and 18 per cent increases in productivity due to good seed preservation—differences equal to those often obtained in testing the leading corn varieties of a state. This shows that many so called variety tests of corn could be as properly called tests of good or bad seed corn preservation, while in fact they are unreliable tests of either since it is not known whether the variations in productivity are due to heredity or to methods of seed preservation.

In a number of these tests the different methods of seed preservation did not affect germination, but did affect the productivity of the seed, hence the following statement: The detrimental effects of poor seed preservation upon productivity cannot be measured by the results of germination tests.

It is not difficult to afford uniform preservation to the seed of all varieties to be tested, but this is not sufficient, for we have found that inherited productivity is not revealed by field tests unless the seed of all varieties has grown and matured under similar condition of soil and climate.

It is generally conceded that acclimatization and adaptation have their influences, but it has recently been proved that with corn these

influences sometimes operate within such narrow bounds, and so promptly as to mislead the student of heredity. To illustrate this point: A fifty mile separation for five years without any cross-breeding, has proved sufficient to acclimate and adapt a strain to such an extent that it consistently outyielded in water-free corn the original strain ten per cent in the new locality and as consistently fell 30 per cent below it in the old locality. In this test identical lots of seed were extensively tested in both localities. Results of this kind do not preclude the possibility of increasing the productivity of a variety by taking it to an environment to which it is better adapted.

One would conclude, therefore, that to be of value in studying the effects of parentage upon corn yields, all lots of seed to be tested must be produced in the same locality and similarly preserved. But two lots of pure seed of identical parentage produced in the same locality and similarly preserved sometimes show as much as 14 per cent difference in productivity. In these cases parentage, climate and seed preservation were identical and consistent results secured from repeated tests. The lots of seed of lowest yielding power were produced on poor soil and those of highest yielding power were produced on fertile soil.

Going a step further, we find experimental proof that seed grown under very droughty conditions may be much lower in yielding power than seed of the same parentage grown under conditions of sufficient rainfall. Tests made in Texas and in Maryland of two lots of similarly bred seed of Boone County White, proved that the seed grown in Maryland exceeded in yield the Texas grown seed to as great an extent as is usually found between different varieties.

Age of seed and its ability to germinate have in some tests been given consideration, while less obvious factors, such as environmental conditions during seed formation, adaptation, and seed preservation, have been ignored. Since any one of these three last mentioned factors sometimes influences the yielding power of seed corn to as great an extent as does parentage, it is evident that effects of corn breeding upon productivity can not be demonstrated without taking these factors into consideration. These factors have received special mention in this paper because tests made by the Office of Corn Investigations have shown that they have in certain instances, influenced productivity to a greater extent than did cross breeding.

Test plat work has been so faulty that there exists a tendency to attribute most all conflicting results to unreliable test plat work. As test plat methods are being rendered more reliable, it is becoming

apparent that conflicting results are somtimes due to influencing factors nor previously considered.

It is regretted that the limits of this paper do not permit a presentation of the details and technique of the various experiments that have prompted the above summary statements. The details and technique of work supporting some of these statements are given in Bulletin 218 of the Bureau of Plant Industry of the United States Department of Agriculture. The results are mentioned on this occasion to bring to mind the fact that our close search for experimental evidence to support principles of corn breeding may have caused us to attribute to heredity effects due to some peculiar physical, physiological or pathological condition of the seed.

TESTS WITH FIRST GENERATION CORN CROSSES

L. L. ZOOK

Washington, D. C

It is the purpose of this paper to deal with the results of tests in which the yields of crosses have been compared with those of their parent varieties. The discussion will be confined to what these tests seem to indicate of the practicability of the utilization of F_1 crosses in corn improvement.

This subject of the value of first-generation crosses has been given considerable attention recently and it is important that it be weighed yet more thoroughly before being either endorsed or condemned.

Whether it be attributed to prepotency of the better parent to rejuvenescence, to heterozygosis, or to some other cause, it seems to be quite universally recognized that F_1 crosses between varieties are in the greater number of cases more vigorous and productive than the average of the parents. It is also recognized that in numerous instances one of the parent varieties, and in a few instances both parents, exceed the cross in yield.

For practical purposes we are obviously concerned not with averages, but with those cases in which the crosses are superior in yielding power to their better parents. We are concerned with the amount and constancy of this increase, its frequency and also with what if any parent characters or physiological conditions it is correlated or associated.

The data at hand at the present time on this subject do not furnish conclusive evidence on the points desired. They are, however, sufficiently extensive to make their complete presentation in this paper impossible and have therefore been summarized in the way that seemed best to indicate their value.

The tests of greatest importance with which I am familiar are as follows: Morrow and Gardner,[a] in Ill.; East[b] in Connecticut; Shull[c] in N. Y.; Collins[d] in Md.; Hayes and East[e] in Conn.; Office of Corn Investigations of the Bureau of Plant Industry.[f]

The tests of the Office of Corn Investigations are most extensive and will be considered first. The crosses were made in 1909 and tested

TABLE 1.

Crosses made in.	Location of test.	Variety Used as ♂ parent.	Number of varieties crossed.	Comparison of crosses with better parent.		
				No. more productive.	No. less Productive.	Average per cent of Increase.
Maryland	Maryland	U. S. Sel. 119	18	4	14	−3.6
Maryland	California	Do	18	9	9	2.2
California	California	U. S. Sel. 160	2	0	2	−9
Texas	Texas	Chisholm	15	4	11	−8.3
Texas	Texas	Do	12	10	2	7
Texas	Texas	Do	14	8	6	4.2
Georgia	Georgia	Rodgers W. Dent	10	8	2	3.5
Georgia	Georgia	Marlboro Prolific	10	8	2	5.6

in 1910 in comparison with their parent varieties. As shown in Table I, the tests were made in four states and with a total of 44 varieties. The distribution was as follows; 18 varieties, crossed with a single variety, in Maryland, grown in two locations, in duplicate plantings, near Washington, also tested at Chico, California; 2 varieties crossed with a third at Chico, California, grown at the same place; 15 varieties crossed with a single variety at Waco, Texas, grown at Waco, Corsicana and Sherman, Texas; 10 varieties crossed separately with two varieties at Statesboro, Georgia, grown at the same place.

[a] Ill. Exp. Sta. Bulletins 25–31, 1902–03.
[b] American Naturalist, vol. 43, no. 507, 1909.
[c] A.B.A., vols. iv, v, and vi, 1908–9–10.
[d] Bur. Pl. Ind. Bulletin 191, 1910.
[e] Conn. Exp. Sta. Bulletin 116, 1911.
[f] Bur. Pl. Ind. Bulletin 218 (in press).

The Maryland test furnishes the most accurate results as it is made up of the combined results of four tests, each in itself as large and carefully conducted as are ordinary tests of this kind. In this only 4 crosses out of 18 proved more productive than their better parents, the average per cent of increase over the average of the better parents being— 3.6. It might be said of these crosses that they were not representative, as they have a common male parent which may be one which does not perform well in combination. This conclusion seems not to be evidenced, however, by the four cases in which the crosses exceeded the better parent. In one of these cases the increase was was 20 per cent. In California the crosses were evenly divided in number below and above the better parent, and the average increase was not large. The two crosses made in California both proved inferior in yield to their better parent. In the three Texas tests in

TABLE 2.

Investigator.	Location.	Year reported.	Number of varieties crossed.	Comparison of crosses with better parent. Number more productive.	Number less productive.	Average per cent of inc.
Morrow and Gardener..	Illinois	1892	5	3	2	4.6
East....................	Connecticut	1909	2	2	0	5.8
Shull....................	New York	1909	2	1	1	2.0
Collins..................	Maryland	1910	14	10	4	9.4
Hays and East.........	Connecticut	1911	2	2	0	4.9

which the same crosses and varieties were used, one test gave results opposite to the other two, both in having a majority of crosses poorer than the better parent and in a negative percentage of increase. In the Georgia tests the crosses with each male parent gave a greater number above than below the better parent, although the percentage of increase was slightly greater with one sire than with the other.

Results of tests by other investigators, previously mentioned, are given in Table 2.

The following points should be kept in mind in the consideration of these results.

In the tests of Morrow and Gardener in Illinois, the comparison of productiveness must be given considerable latitude, as the crosses and parent varieties were in some cases quite widely separated in the field. Collins does not claim great accuracy for his results for as he

says "The experiment was considered as merely preliminary and but 16 hills of each variety were grown."

Hayes and East report six crosses in addition to the ones included in the table, but in each case one or both parent varieties had been inbred and their yields consequently do not furnish a fair basis of comparison.

The results summarized in the two tables furnish the best information with which I am familiar on the question of the practical value of F_1 crosses in corn improvement.

But one thing seems to be clearly shown, namely, that no uniformity of performance can be expected. There are a few more instances in which the crosses have proven more productive than their better parents than in which the reverse is true. In the majority of tests likewise the average per cent of increase of the crosses over the average of the better parents has been positive. It is, however, usually not large, in no case exceeding 10 per cent.

These counts and averages are valuable in showing tendencies, but greater interest and importance attaches to the behavior in individual cases. If as in the Maryland test of Table 1 only 4 out of 18 crosses proved advantageous and the average per cent of increase proved to be negative, the results could not be discarded in total without first examining the advantageous crosses. As has been pointed out, in one of these advantageous crosses the increase in productiveness over the better parent was 20 per cent. Attention is again called to the fact that the Maryland test is the combined result of four separate tests. In every test reported in which several varieties were crossed some of the crosses have proved more productive than either parent. The maximum increases over the better parents for the different tests of Table 1 ranged from 16 to 31 per cent. The cases in which large increases have been obtained are relatively few, but this can hardly be made an argument against their value. It is only out of a large number that the best combinations can be expected to be found.

Usually the best producing crosses come from the best producing parents for a given locality. There are, however, sufficient exceptions to this rule to indicate that there are other influencing factors. Although we know very little of the cause the greatest factor in determining whether a cross shall be advantageous or not seems to be that of congeniality or the lack of it in mating; that is, some varieties combine better than others and whatever the cause, what these varieties are can only be learned by actual trial.

Shull[8] has pointed out, that the yield of a cross between two pure strains of the same variety is not the result of a mere chance relation but a specific function of the particular hybrid combination which produced it, with the result that essentially the same yielding capacity is maintained in successive years. While this may hold for crosses between strains which have been simplified by inbreeding, it does not necessarily follow that a cross between two distinct complex varieties would perform in the same way. It is a well known fact that the relative production of a series of varieties will vary from year to year. This may be attributed to the various biotypes or subspecies composing each variety being affected in different ways by different factors of climate and soil which accelerate or retard development. Whether or not the change in composition is of such a nature or sufficient in amount to affect the congeniality of varieties in mating or the amount of stimulus from crossing, can only be determined by continued experimentation. It may be found that the same pairs of varieties must be crossed several times before the full value of their F_1 crosses can be determined.

It has been pointed out that the increased vigor possessed by crosses might enable them to overcome to some extent the effects of local adjustment and that they could consequently be used to better advantage than pure seed for wide distribution and extension of the corn belt. It seems reasonable to conclude, however, and the meager data we have on this point seems to bear out the conclusion, since some varieties are more productive than others of about the same length of growing season in certain localities, and other varieties are more productive in other localities, that crosses would behave in much the same way. We find that some of the best producing crosses in Maryland were among the poorest in relative production in California, while some of those that gave best results in California were poorest in Maryland. This was true not only when the relative production of different crosses were compared, but also when the crosses were compared with the parent varieties.

Another point that should be considered in this connection is whether increased vegetative vigor is always a desirable character. Increased vigor as a result of crossing would doubtless be accompained by increased grain yields under optimum conditions, but there are large corn growing areas in which such conditions seldom obtain, and increased vegetative vigor might result in a corresponding decrease in grain yield. In certain regions of the South cultivation and appli-

[8] Hybridizing Methods in Corn Breeding, A.B.A., vol. vi, pp. 67–68.

cation of fertilizer is arranged with the purpose of retarding excessive vegetative growth. In the drier portions of the West large stalk growth often exhausts soil moisture so that there is not sufficient remaining to develop large grain yields.

It seems then that it may not only be necessary to make the same crosses several times in the same locality, but that like trials will need to be repeated in many localities to meet the conditions and requirements found therein.

The tests so far have been as suggestive as conclusive. While they have indicated much of what can be expected from crossing varieties of corn the necessity of further work along the same line has been emphazised. In planning future tests of this kind the experience gained will furnish a clearer idea of the objects sought, methods to be employed and mistakes to be avoided.

While yields are of primary importance other advantages, such as earlier maturity, insect protection and the like, which may be gained in a greater degree by transference of characters through crossing, should not be lost sight of.

In these, as in all tests in which yields are to be compared, extreme care should be given to secure uniform soil and stands of stalks. The seed of crosses and pure varieties used should be of the same age, produced and preserved as nearly as possible under the same conditions. Plantings should be so arranged that competition between varieties that differ widely shall operate at a minimum. Moisture determinations of each variety and cross should either be made, or all carefully dried before weighing.

PROGRESS REPORT ON CORN BREEDING

C. G. WILLIAMS

Wooster, Ohio

In continuation of the report in volume V, page 171, of the American Breeders' Association, I desire to call attention to the pedigrees of certain strains of corn which have descended from the most productive ears of an ear-row test conducted in 1905, as recorded in Table 1, and the average yields of these several strains as they have been tested from 1907 to 1911, as recorded in Table 2.

There are 13 distinct pedigreed strains reported upon, all but two of which trace back on either the male or female side to the best four ears of the test of 1905.

In the production of these 13 strains, 17 different ears have been used—the highest in yield in their respective ear-row tests. These foundation ears are illustrated on pages 345, 346, 347, 348.

TABLE 1.—*Pedigrees of pure bred strains of corn.*

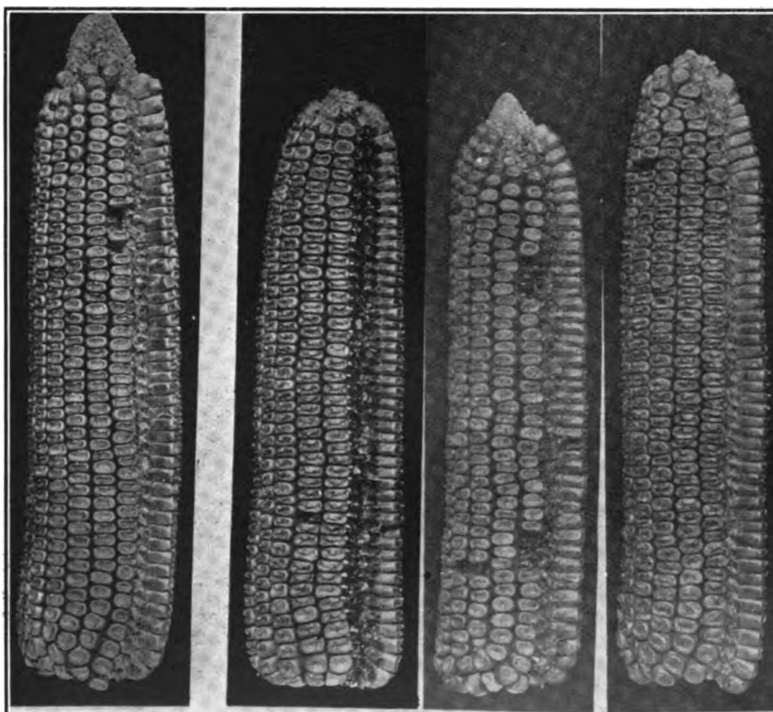
Group.	Strain (O.P.B.A No.)	Sire.	Dam.	Dam's sire.	Dam's dam.	Sire's sire.	Sire's dam.	Dam's grand-sires.	Dam's grand-dams.
1	41	17-5309	17-5307		Field Sel.		4213		
	42	17-5309	17-5311		4225		4213		Field Sel.
	43	17-5309	17-5313		4208		4213		3117
2	95	54-7044	54-7034	17-5309	17-5313		Field Sel.		4213 4208
	96	54-7044	54-7048	17-5309	17-5311		Field Sel.		4213 4225
	97	54-7044	54-7055	17-5309	17-5313		Field Sel.		4213 4208
3	202	90-8058	90-8037		Field Sel.		Field Sel.		
	203	90-8058	90-8039	17-5309	17-5313		Field Sel.		4213 4208
	204	90-8058	90-8040		Field Sel.		Field Sel.		
	205	90-8058	90-8053	17-5309	17-5311		Field Sel.		4213 4225
4	315	233-9036	233-9032	17-5309	17-5307	17-5309	17-5311		4213 Field Sel.
	316	233-9036	233-9040	54-7044	54-7048	17-5309	17 5311	17-5309	Field Sel. 17-5311
	317	233-9036	233-9041	54-7044	54-7048	17-5309	17-5311	17-5309	Field Sel. 17-5311

TABLE 2—*Yields of pedigreed strains of corn.*

Group.	Strain (O. P. B. A. No.)	Years tested.	Av. yield for years tested.	Av. yield of checks for years tested.	Av. + or − over check.
1	41	1907–08	77.45	79.43	−1.98
	42	1907–08	84.41	79.43	+4.98
	43	1907–08	83.68	79.43	+4.25
2	95	1909–10–11	80.67	74.43	+6.24
	96	1909–10–11	82.67	74.43	+8.24
	97	1909–10–11	81.74	74.43	+7.31
3	202	1910–11	64.72	61.04	+3.68
	203	1910–11	66.24	61.04	+5.12
	204	1910–11	62.51	61.04	+1.47
	205	1910–11	69.57	61.04	+8.53
4	315	1911	85.98	78.22	+7.76
	316	1911	85.89	78.22	+7.67
	317	1911	88.39	78.22	+10.17

The pedigreed strains in question have been tested each year in the Experiment Station's variety corn test—a test conducted upon one

of four ranges which are devoted to this work. These ranges consist of about 100 tenth-acre plots each, and are farmed in a 4-course rotation of corn, oats, wheat and clover. Twenty-five to 33 of each 100 plots have been planted to the same check variety each year, and the average yield of all of these checks is compared with the yields of the several pedigreed strains of the same season. The difference in yield between the checks and the different strains is indicated in



17-5309 17-5307 17-5311 17-5313

FIG. 1. PARENT EARS OF PURE BRED STRAINS OF CORN.
Sire ear on the left, three dam ears grouped on right.

the final column of Table 2, "plus" signifying the gain and "minus" the loss in yield.

In explanation of the tables let me say that "O. P. B. A. Number" means the number under which the strain is recorded on the books of the Ohio Plant Breeders' Association. No. 42, for instance (see table 1) is the progeny of a cross of ear 17-5309 as sire, and 17-5311

as dam. The dam's dam is ear 4225, and the sire's dam is ear 4213. The Ohio Station exercised no control of the sire in its corn breeding work prior to 1905, hence the balance of the table is a blank for strain 42. The figures before the dash in all columns after the first in Table 1, indicate the O. P. B. A. record number of the ear-row test in which the ear in question was tested. The figures after the dash, the number of the ear, the first figure of which indicates the year of the test. For

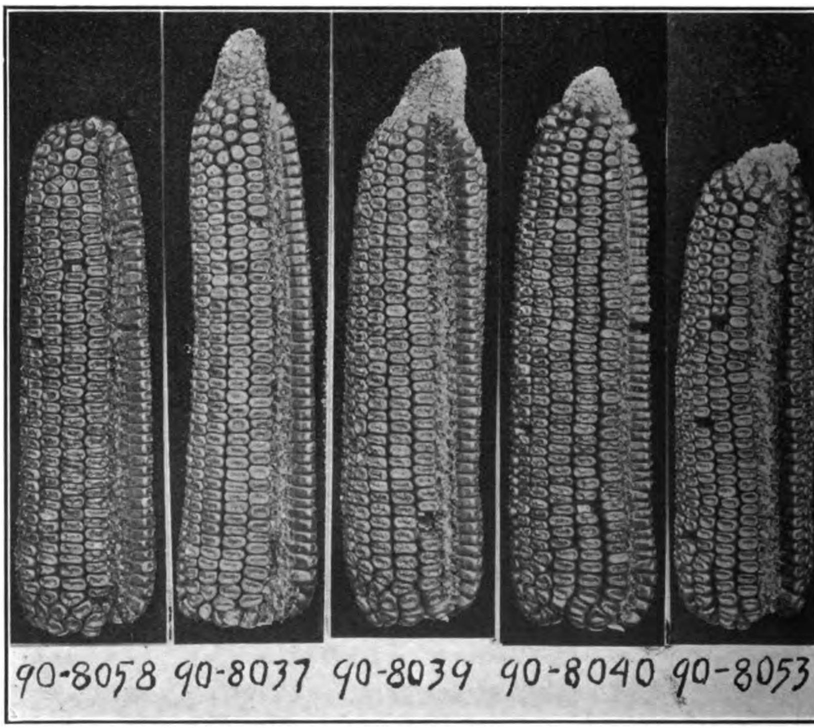


FIG. 2. PARENT EARS OF PURE BRED STRAINS OF CORN.
Sire ear on left, four dam ears on right.

instance: The sire of strain 42 is ear 17-5309. 17 is the record number of the ear-row test on the books of the record association, while the figure 5 indicates that the ear was tested in the year 1905.

Consulting Table 2 it will be found that the average yield of strain 42 in the years tested was 84.41 bushels per acre, and that the yield of the check plots for the same two years was 79.43 bushels, the pedigreed strain thus outyielding the checks by 4.98 bushels per acre. Photographs of the foundation ears of strain 42 are shown on page 345.

In the earlier years of this breeding work we usually found some new ear selected from the field standing in the list of eligibles in each ear-row test; i. e., not ranking lower in yield than fourth. In this event the new ear was generally used as sire in the breeding plot of the following year, for the sake of avoiding too close breeding. It is for this reason that the column headed "sire's sire" in Table 1 is

FIG. 3. PARENT EARS OF PURE BRED STRAINS OF CORN.
Sire ear on the left, three dam ears on right.

blank until the fourth group of pedigreed strains. Some few of these new selections from the field gave evidence of merit as producers, though of unknown ancestry. It is noticeable, however, that when crossed on high producing dams which were also selected without knowledge of ancestry, the resultant strain has proved decidedly inferior, as notice numbers 202 and 204 in both tables. This would

seem to offer pretty good evidence that the character of yield is hereditary.

The data offered call for very little comment. It is noticeable that strain 41 is the only one of the series which has given a yield below the average of the checks. It should perhaps be said that the yield of the dam of this strain (ear 17–5307) was the lowest in yield of the

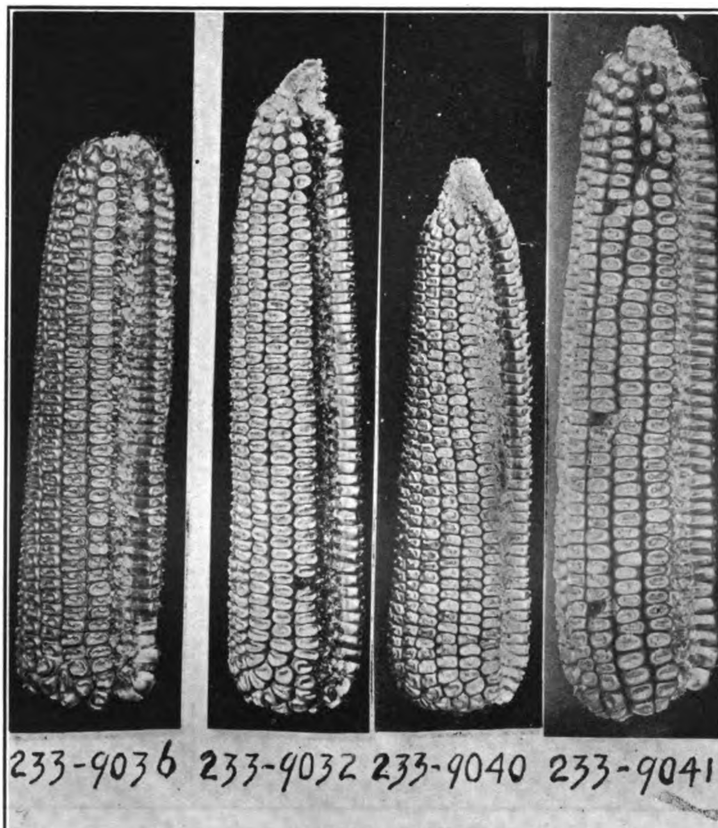


FIG. 4. PARENT EARS OF PURE BRED STRAINS OF CORN.
Sire ear on left, three dam ears on right.

four ears saved from the ear-row test of 1905—a fact not shown by the table; that it is the only dam of this series of which nothing is known of its ancestry; and, further, that while as many ears of this strain were tested in all subsequent ear-row tests as from strains 42 and 43, yet in the pedigree of only one strain (315) does ear 17–5307 appear, for the reason that the others fell by the wayside. Foundation ears

17–5311 and 17–5313 appear repeatedly—still further evidence of the value of breeding.

Comparing the gains in yield in the second group (strains 95, 96 and 97) with the first group, it will be noted that they are uniformly higher. In the third series, with one exception, the gains of the different strains, as compared with the check, drop back. At first thought this looks as though the limit had been reached with the strains of the year previous; but note, first, that the two strains (204 and 202) showing poorest gains are the strains without any breeding back of them, to which attention is called above, and, second, that there is one strain of the group (205) which exceeds any gain yet recorded.

In the fourth group, as tested in 1911, we have the highest gains recorded. The *average* gain of the three strains tested, slightly exceeds the gain of any previous *single* strain, while the *best* strain leads every other strain by a nice margin. It should be noted that in this group we have the latest generation in this system of breeding—the longest and most complete pedigrees.

It is of further interest to note that the best strain of group 4 (317) the best strain of group 3 (205) and the best strain of group 2 (96) all trace to the best strain of group 1 (42), the produce of the cross of ear 17–5309 on ear 17–5311. As we have other crosses in which ear 17–5309 is used as sire, it is probable that the dam (ear 17–5311) is the source of much of this merit. This line of progeny would seem to be a vindication of the value of breeding, if not of good looks.

IMPROVEMENTS IN TECHNIQUE OF CORN BREEDING

G. N. COLLINS

Washington, D. C.

Any change in apparatus or methods that will enable the work of breeding to be done more expeditiously or with more accuracy is worthy of serious consideration. Taylor's principles of scientific management might very profitably be applied to the operations of breeding. If, without sacrificing accuracy, the time necessary to make a pollination could be reduced by one minute, it would very materially increase the results, even in a single season. This is particularly true in corn breeding where the nature of the plant crowds the work of pollination into a few weeks or even days.

In our work we have hit upon a number of little devices almost foolishly simple that have proved to very materially increase efficiency. Few of the methods are original, most of the suggestions having been received from friends engaged in other lines of scientific work and consequently not hampered by conventional methods. It is not supposed that any of the methods are the best that can be devised, and only a few of them can be mentioned at this time. It is hoped, however, that attention will be called to the possiblilty of simplifying the little operations that are constantly being performed, operations that in the aggregate consume a large part of the breeder's time.

Labeling.—In the use of labels there are two common sources of error that have to be avoided; the shifting of labels and mistakes in copying. To guard against the first it seems desirable to use a label that is small enough to go in the package of seed so it will not be necessary to make comparisons between the stake and package labels in the field when the seed is being planted. We have found embossed labels made on metal ribbons by a hat-marking machine the most satisfactory.

To guard against mistakes in copying, each row or progeny has a double designation; in our work, a formula and a name. The formula is a cipher description of the history of the stock, while the name has no special significance except as a designation more easy to remember than a number. The important feature is that both the formula and name are different for each planting. Any mistake in copying the label can thus be detected, for if either the formula or the name is wrongly copied it will result in an incongruous combination, a formula and a name that do not belong together. This prevents the note or the seed being referred to a wrong progeny. The same result could, of course, be secured by using a double number. Mistakes in copying which place the crop of a progeny in a wrong class are so serious that I believe some such double system of labeling is essential.

Bagging the tassels.—In the bagging of tassels to secure pollen, we have found transparent paper bags a great improvement over the ordinary manila bags. This suggestion came from Mr. J. B. Norton, who used such paper bags in his breeding work with asparagus. It is necessary to remove opaque bags before one can tell whether pollen has been shed or not, but with transparent paper this can be seen without removing the bags.

In addition to being transparent these bags are to a considerable extent water-proof. They will not keep pollen dry during a protracted

rain, but many light showers that necessitate the changing of manila bags do not injure the pollen in the transparent bags. The transparent paper never becomes sodden and is, therefore, much less liable to break the stalk. The light weight has a further advantage in reducing the load to be carried by the operator in the field.

Small bags of the same material, if carefully glued, provide a useful method of storing pollen. The transparent paper makes it possible to see how much pollen of a certain kind is on hand without the danger of contamination incurred by opening the bag.

Bagging the silks.—For covering the silks we have found that time can be saved by the use of bags provided with openings at both ends. We have used the ordinary manila bags by cutting off the bottom and closing the opening with paper clips, but a more convenient method is to use long "coin bags" made with the bottom left open and closed by patent fasteners. These bags are placed over the ear with the closed end away from the plant. Instead of removing the bag to apply the pollen, the pollen is introduced through the other end. By this method it is quite unnecessary to touch the silks at all, thus lessening the danger of contamination with foreign pollen.

As soon as the pollen is introduced and the opening closed, the bag can be agitated to insure a thorough distribution of the pollen. This permits the use of a much smaller amount of pollen.

A simple trick that makes pollination more certain and also saves time is to cut the tip of the ear when the bag is applied. The cut should, of course, miss the end of the cob but should be low enough to expose a cross section of the silks. In twenty-four hours after the ear has been cut and the bag applied there will be a brush of silks from ½ to 1 inch long, all exserted a nearly equal distance. A very little pollen will then suffice to pollinate all the silks, and the time wasted in taking off bags to look at ears not ready to be pollinated is saved. Unless the cutting is done too early, a second pollination is seldom necessary.

The experiment was tried of placing a little pile of pollen on the cut surface of the silks as soon as the tip of the ear was removed, but pollinations made in this way were very imperfect.

Wire.—When open bags are used and the bags are not removed, it is necessary to provide for the expanding ear. Even with the old system considerable inconvenience was occasioned by the wire cutting into the ear or breaking before harvest. This can be avoided by using a coiled wire that expands with the growing ear. The wire can be easily coiled by wrapping around any small pointed object,

such as the point of a lead pencil. No. 20 unannealed copper wire has been found a satisfactory size.

Ear labels.—In the early stages of our work we were very seriously annoyed by the labels dropping off the ears. We tried wiring the labels to the ears, but as the ear dried the wire became loose and dropped off. We tried fastening the labels to the butt by long pins or slender nails, but the drying of the pith loosened the nails. A suggestion by Mr. G. S. Meloy that the labels be attached by "pig-rings" finally solved this difficulty. The rings are quickly and easily applied by means of the special pliers furnished with the rings, and very seldom become loosened.

In addition to their use in attaching labels, the pig-rings afford a very convenient method of supporting the ears while drying.

To harvest and dry the ears, we use frames about 2½ feet by 5 feet, made of light wood and supported on stout legs about 18 inches high. Across these frames, loose pieces about ⅞-inch square are laid. The pieces are provided with wire hooks from which the ears are hung by means of the pig-rings. In our plantings, one stick will usually hold the ears of a single progeny, and forms a convenient method of handling the progeny as a whole. Placed close together on the frame, the ears occupy little space, yet each ear is free and dries perfectly. The frames are stacked one on another, and are mouse-proof.

Self-pollination.—For making self-pollinations, of which many are necessary in the study of Mendelian ratios and reversions, a method has been devised which not only reduces the labor but practically eliminates the possibility of accidental pollination by foreign pollen.

The method involves the use of long paper tubes with one end attached to the tassel, the other to the ear. The tassel is bent over to one side, and as fast as the pollen is produced it falls down the tube and comes in contact with the silks. By this method the silks are never exposed and the danger from foreign pollen is practically eliminated.

This method is described and figured in Circular 89 of the Bureau of Plant Industry of the Department of Agriculture.

METHODS IN THE ARTIFICIAL POLLENATION OF CORN

W. B. Gernert

Champaign, Illinois

During the last three years the writer has been engaged upon a study of characters in corn, at the Illinois Agricultural Experiment Station.[a] Had the information which was gained in regard to technique during this study on heredity been available at the beginning of the work, it would have been of very great value. The purpose of this paper is to present a few of the facts learned in the belief that they may be of use to others.

Since corn is propagated from the seed and since it is wind pollenated and thus continually exposed to mixture, unless it is completely isolated, improvements in methods concerned with its hand pollenation will always be welcomed. Where large numbers of individuals are being used, an improvement in one detail of the work is often of immense value in time saved at a period when time is precious and in the increased results accomplished.

Studies of characters *en masse* and in mixed population would probably never have solved the riddle of inheritance. As Bateson has pointed out, the main fact in Gregor Mendel's great discovery was *segregation*. Mendel studied *characters* and not individuals. Careful scrutiny of characters in the controlled, successive progeny of two individuals was the secret of Mendel's successful analysis of the behavior of characters.

The first problem that confronts one if he wishes to keep careful pedigree records of characters in parents and their progeny, is that of devising a simple and convenient system of numbering which will permit easy classification of cases and generations. A large list of varieties was used in my own work (begun in the fall of 1908), including all of the six species-groups recognized by Sturtevant, whose classification has come into general use.

For convenience the six groups were given numbers 100 to 600 in the order in which Sturtevant arranged them.[b] The varieties and strains, as they were obtained, were given acquisition numbers by consecutive units within the groups to which they belong. If a new

[a] The writer wishes to acknowledge indebtedness to Dr. L. H. Smith, to whom much credit is due for suggestions and aid in the work.

[b] U. S. Dept. Agri., Off. of Exp. Sta. Bulletin 57:7-108, and elsewhere.

group were recognized generally in the future it would be given the number 700.

The particular strain of Reid's yellow dent which I used was the seventh in the list of some sixty dent corns (No. 400) and it was numbered 407. This system not only indicates what group the parent is in but lends itself admirably to field use, where brevity is essential.

The Reid's yellow dent was planted in row No. 42 in the field. The labels on the plants in that row bore the numbers 407, 42–1, –2, –3, etc. The variety of sweet corn known as "Country Gentleman" was the 6th in its group and was planted in row No. 86. Hence the plant labels in this row were given the numbers 606.86–1,–2, etc.

The row numbers were used with that of the parent number because there was more than one row of the same strain. Plantings of the same variety were made at different dates in order to secure pollen of varieties having a short growing period to use on the silks of others having an extended growing period. Differences of 20 to 30 days, or more, must be used in time of planting in some instances because later plantings develop much more rapidly than do the early plantings. It was also sometimes necessary to plant more than one row of the same hybrid progeny in order to get sufficient numbers to diminish the probable error of segregation.

If varieties Nos. 407 and 606 were hybridized and the resulting seed planted in the next season all figures were dropped except the ones indicating the groups to which the parents belonged. If 606 were used as the sire the row labels might read 46.357–1,–2,–3, etc. This field number would then be interpreted as follows: an F_1 dent-sweet hybrid on row 357, plant number–1,–2,–3, etc. A larger number than this is undesirable for field use. For convenience, the parent numbers $(407 \times 606)_1$, $-_2$, etc., are placed at the top of the initial data sheet of the fields notes for the case. The sub-indices ($—_1$, $—_2$, etc.) denote certain cases of hybrids and their reciprocals. Similar sub-indices are used preceding the decimal on the field row label to indicate the second and third generation of the progeny.

Conspicuous labels at the head of each row are desirable to facilitate the taking of notes and the locating of special individuals in the field. It is best to use wood or cloth lables with wire ties on the plants and ears to avoid loss by wind, rain, and vermin. A planting plan of the entire field should be kept on hand as a check on the field numbers.

The practice of growing two or more plants in the same hill is undesirable for several reasons: It is much easier to be exact in dropping only one kernel in a place in such work as this where hand

planting is necessary. If differences in sucker production are under investigation it is very difficult to interpret results when several plants are growing in the same hill. In cases where relative size, shape, number of parts, vigor, and yield are under observation, it is very undesirable to plant closely or with more than one plant in a hill, because of the marked influences which competition and environment have on the development of the corn plant. Confusion and delay in taking notes and in pollenating work are also avoided when plants are well spaced and only one in a hill.

It is advisable to use a different field each year and it is best to use one that has not been in corn during the year previous. This procedure prevents mixture by volunteers which are commonly found in a field that has been in corn the year before.

The materials absolutely necessary for the hand pollenating of corn, without contamination in the process, are few and simple. For one plant,—two 10 pound manila grocer's bags for protecting the shoot and gathering the pollen, two brass pins for fastening the bags to the plant, and a large newspaper or an umbrella expanded over the shoot while pollenating it, are all that is needed. For regular work continuing through days and weeks, certain conveniences are essential.

In the season of 1909 the writer began with using ten-pound manila bags to protect the shoots, but within ten days a severe rain storm riddled all the bags. A large number of hand pollenated ears and shoots not yet pollenated were thus lost by exposure to stray pollen after the storm. Bags two-thirds the width and length of the ten-pound manila bags, of tough parchment paper, were then made especially for this work. The paper in these bags is similar to but of a better grade than that generally used for cartons in which salted peanuts are sold. These transparent bags are also very desirable because they permit inspection of the silks without removing the bag, to learn whether the shoot is ready to be pollenated. Very little loss due to storms has occurred since this kind of bag has been used.

Some workers have used cloth bags but these are unsafe, as a simple test of dropping pollen on a piece of the cloth held expanded over a solid surface will show. Cobs may be obtained without kernels when protected by cloth bags and not pollenated, but in a thorough test, with what were thought to be tight cloth bags, many of the inclosed cobs were found to have a number of kernels upon them. The best grade of bagging cloth, especially when exposed to the weather, will show small holes through which pollen may sift.

In 1910 ten pollen grains from each of 1 to 3 representative individuals in each of various varieties were measured:

Size of pollen grains of various varieties (in millimeters).

Variety number.	Description of varieties.	Character of pollen grains.			
		Number measured.	Breadth mode.	Length mode.	Shape mode.
104.4-A	Pod Corn (medium kernels)	30	0.094	0.146	Ellipse
104.4-B	Pod Corn (do.)	30	0.090	0.098	Pyriform
204.14	Yellow Rice Pop (very small kernels)	30	0.078	0.086	Ellipse
206.16	Red Pearl Pop (small kernels)	30	0.086	0.098	Pyriform
211.0	Yellow Pearl Pop (Tom Thumb-small kernels)	10	0.090	0.094	Ellipse
212.22	White Rice Pop (very small kernels)	30	0.078	0.086	do.
213.0	White Rice Pop (do.)	30	0.078	0.086	do.
304.0	White Flint (very small plants—early)	20	0.086	0.098	do.
402.37	White Dent (Hickory King—large kernels)	30	0.082	0.098	do.
442.77	White Dent (Cob pipe corn—med. kernels)	30	0.086	0.098	Pyriform
504.01	Soft corn (medium kernels)	30	0.090	0.098	Ellipse
612.22	Sweet corn (Egyptian—medium kernels)	30	0.090	0.102	do.

These measurements which include representatives of all of the six species-groups, indicate that the average diameter of the pollen grain of corn varies from approximately 0.08 to 0.1 of a millimeter, and that cloth would need to be very densely woven to exclude a pollen grain of this size. The data also show that the pollen grain of corn is not exactly spherical, contrary to the reports of some writers. The pollen grains when first shed are smooth and glistening, resembling pearls under the microscope, but they begin to shrink at once in the atmosphere and on a warm summer day they are considerably collapsed at the end of a half hour; yet these shrunken pollen grains germinate. There is apparently no difference in size or shape of the pollen grains of different varieties that would affect their germination or their receptivity by silks of other varieties on which the pollen may be used.

There was no evidence that widely diverse varieties would not hybridize when fresh silks and pollen were available. Varieties were successfully hybridized that differed very markedly in the dimensions of the kernel. Hybrids were obtained where one of the parents had kernels which averaged more than 38 times greater in weight and more than 39 times greater in volume than the average size of the kernels of the other parent. Other hybrids were secured in which the average specific gravity of the kernels of the parents were 1.4 and 1.0 respectively. Some parents of hybrids produced plants averaging 6 times the height of the other parents. Many other wide extremes were hybridized.

When the pollen of several different varieties is mixed and used as a composite on one shoot, the pollen of one or two of the varieties used may fertilize nearly or all the ovules on the ear. Whether this exclusion of some of the pollen grains is due to poorer germination, difference in receptivity, or difference in vigor in the pollen of different individuals or varieties, has not yet been determined.

A large number of shoots inclosed in the parchment paper bags were not pollenated because of lack of pollen, extreme age of silks, or because of the amount of work at hand which prevented using all of the bagged shoots at the proper time. From many of these the bags were not removed until harvesting time, when an examination of these protected cobs disclosed quite a number of cases in which there were from one to a half dozen kernels.

Stray individual kernels were sometimes found on the hand pollenated ears that were plainly mixtures, and such cases cannot be prevented with absolute certainty. On the hand pollenated cobs the mixture may have been due to contamination, but on the undisturbed cobs the mixture may have been due to break in the bag, to stray silks growing down through the crevices at the mouth of the bag, or to insects which have entered the bag and carried pollen upon their bodies.

In the instances of mixture we are inclined to lay most of the blame upon the small insect *Diabrotica longicornis*, which in the larvae stage is known as the corn root worm. This insect is a voracious feeder on pollen and silks and proved a serious pest in our pollenating work. It was frequently found within the bags when they were opened and the silks were often damaged so that the shoot had to be discarded. Dipping the base of the bag in some repellant might be used to good advantage.

The shoot is usually allowed to grow unprotected until two days previous to that in which the silks are expected to appear. Bagging very young shoots is harmful to their development and sometimes stunts the shoot so that no silk appears. In a number of instances the second, unbagged shoot put forth silks considerably before the upper bagged shoot, while in general most varieties expose silks on the upper shoot first when the plant is normal and unmolested.

The method of bagging shoots, which was found to be most convenient and satisfactory as a protection, was as follows: The leaf at the shoot bearing node is generally broken down at the top of the shank and removed. The bag can then be readily slipped over the shoot about which it is fastened (not too tightly—as some room must be allowed for the expansion of the shoot) with an ordinary

brass pin. "Bank" pins are preferable because they are of a better grade and have sharper points than the ordinary shop pin. In some varieties the shoot does not protrude much beyond the leaf sheath even at silking time, and in such instances the leaf sheath may be slit by means of a fine wire, when the bag may be inserted as before and pinned to the leaf sheath if there is not room upon the shoot. A leather finger shield is a convenience for pushing the pins. This method is very rapid and a large number of bags may be attached by one man in a day. As a rule there is no need of giving the bags a second attention before pollenating, and at this time the shoot has usually grown enough to allow a final adjustment of the bag. The bag is left on two weeks or more after the shoot is pollenated and then removed to prevent moulding and rotting of the ear.

In the season of 1909 the writer took daily notes on the blooming of a large number of individual plants in many varieties. The results of these observations are shown in the table below.

Distribution of individual plants by number of days intervening between appearance of tassel and anthers.

	Days intervening.																						
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Pods (180 individuals in 3 varieties)...............	2	2	1	1	3	5	15	14	17	30	27	29	10	10	4	4	2	2	1		1		
Pops (556 individuals in 10 varieties)...............	3	1	2	20	26	36	51	77	92	92	72	39	27	7	6	1		3	1				
Flints (591 individuals in 12 varieties)............	2	4	7	8	18	45	57	83	99	112	70	47	23	11	1		1	2		1			
Dents (1319 individuals in 19 varieties)............	35	43	58	77	78	88	125	158	212	191	127	77	34	7	6	1		1	1				
Softs (62 individuals in 2 varieties)...............					1	3	11	16	12	11	3	2	1	2									
Sweets (611 individuals in 11 varieties)............	2	6	4	9	18	28	39	75	81	78	95	81	53	22	7	3	3	2	3	1			1
Totals (3319 individuals in 57 varieties)............	44	56	72	115	144	205	298	423	513	514	394	275	148	59	24	9	6	10	6	2	1		1

These data were taken primarily to study the inheritance of any differences in behavior which might be found. The season was very dry and the plants were grown on very poor soil but the data secured represent what is at least possible behavior in corn. It is apparent that approximately 8 days was the average time between the first appearance of the tassel and that of the anthers.

Occasional plants produced pollen on the same day in which the leaves were unfolded from about the tassel, while the almost incredible time of 22 days elapsed in one instance before any anthers

were observed. The first anthers appeared on more than one-half of all the individuals observed in 7 to 10 days after the tassels bearing these anthers appeared. In securing this data the tassel was said to have appeared when any part could be seen without molesting the leaves infolding it. The plants were recorded as bearing anthers on the day on which the first one on that individual was discovered.

No accurate data were secured on the number of days individual tassels remained in bloom, but general observations showed that this varied from 4 to 10 or more days. The first anther usually appears in the upper region of the central spike of the tassel, while the blooming spreads upward and more rapidly downward. The sequence is similar on the branches. The time at which pollen is shed depends upon weather conditions. On a sunshiny day most of the pollen is shed during the forenoon and sometimes during a shorter period in the late afternoon or evening. Either cold, wet weather or excessive heat may retard or entirely inhibit the process.

Data were also secured on the number of days intervening between the appearance of the anthers or shedding of pollen (anthers of corn shed pollen only on the first day on which they appear) and the putting forth of the first silk from the shoot or female inflorescence:

Time intervening between appearance of anthers and appearance of first silks.

Description of corn.	Days intervening.																	
	−7	−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6	7	8	9	10
Pod (158 individuals in 3 varieties)			1	1	2	2	6	22	24	23	16	21	16	8	9	2	3	1
Pop (495 individuals in 10 varieties)	1				4	5	8	49	93	95	78	60	38	25	9	4	5	4
Flint (395 individuals in 13 varieties)							5	28	42	66	60	63	38	22	22	17	12	10
Dent (1115 individuals in 19 varieties)				3	1	9	34	93	173	182	162	129	86	59	48	35	16	18
Soft (106 individuals in 3 varieties)							7	21	14	12	21	8	10	3	2	4	2	
Sweet (525 individuals in 11 varieties)							6	30	62	93	79	55	42	39	27	23	15	11
Totals: (2794 individuals in 59 varieties)	1		1	4	7	16	66	243	408	471	416	336	230	156	117	85	53	44

Description of corn.	Days intervening.												
	11	12	13	14	15	16	17	18	19	20	21	22	23
Pop (158 individuals in 3 varieties)			1										
Pop (495 individuals in 10 varieties)	4	4	1	1	3		2	1		1			
Flint (395 individuals in 13 varieties)	1	1	3	2	2	1							
Dent (1115 individuals in 19 varieties)	25	13	12	5	3	2	2	1	2	1	1		
Soft (106 individuals in 3 varieties)	1		1										
Sweet (525 individuals in 11 varieties)	11	7	6	4	5	1	2	4	1			1	1
Totals: (2794 individuals in 59 varieties)	42	25	24	12	13	4	6	6	3	2	1	1	1

The individuals which produced no silks are not included in the table. The summary shows that from 1 to 3 days elapsed between the first shedding of pollen and the appearance of the first silks on nearly one-half of all the individuals represented, while the average shows protandry (anthers appearing before silks) of 2 days in length. Although these data show, as has often been stated, that protandry is the rule in corn, a large number of cases (243 individuals) were synacmous (anthers and silks appearing at the same time), while a considerable number (92 out of nearly 2800 individuals) were protogynous (producing silks before anthers). The majority of the protogynous individuals were otherwise apparently normal in development. Selected protogynous plants apparently do not repeat the behavior in their progeny, but our data are at present insufficient to make a definite statement upon this phenomenon. Many varieties are more nearly synacmous than others.

Similar data were taken every fourth day in 1910 and 1911 and upon a much larger number of plants grown on better soil. It is evident from the notes taken in these two years that the above conclusions are reliable in so far as the varieties used are concerned.

In the last two seasons notes were also taken on the time when the husks on the upper ear were dead ripe (devoid of green). A preliminary study of the 1910 data, including a large list (several thousand individuals) of parent strains and hybrids distributed through the six groups indicated that approximately 60 per cent of the total period between the date of planting and the ripening of husks on the upper ear (very nearly the entire growth period of corn), lies between the date of planting and the date of the first appearance of the silks. The actual average time for a large number of cases was 61 per cent. This leaves approximately 40 per cent for the time between the appearance of silks and the ripening of husks.

The data for 1911 have not been summarized, but if this ratio (60 :40) proves fairly constant in other seasons and with other strains, it will afford a simple method for calculating roughly the total growing period under normal conditions when the date of planting and the date of the appearance of silks are known. It is not to be assumed that the ratio 60:40 is absolutely constant even in the same variety as fluctuations of -5 and $+9$ per cent were found in the 1910 summaries, and it is possible that even larger fluctuations may exist in the 1911 data.

Bagging the shoots on the day previous to that on which the anthers are expected to appear safely protects most of the shoots from con-

tamination by falling pollen, and many may be bagged considerably later than this, as is apparent in the table above. The behavior of tassels and shoots can be judged quite accurately after one has had some experience in the work. Tassels are bagged on the day on which the pollen is to be used. It is best to bag the tassels early in the morning before any pollen is shed, in order to decrease contamination by stray pollen grains which may lodge later that same day on the tassel which is to be bagged.

Parchment paper bags were at first used for conveying pollen because the transparent paper allowed the operator to see the pollen as it was used. Their use was discontinued in favor of the 10-pound manila bag which is more easily handled, presents a much better surface for writing notes, and saves a great deal of time, which is an important item. Sometimes a little pollen is wasted with these bags, but there is generally much more than is actually needed when the tassels are bagged at the proper time.

The bags are fastened about the tassel in such a manner that one side is lower than the opening. This provides a pocket in which the pollen may lodge instead of sifting out through the crevices at the mouth of the bag (see fig. 2). A spring clothespin was found to be very convenient for fastening the tassel bags. As these pins are used day after day and will last for a number of seasons they are very economical. The time saved by the use of these pins soon pays for their cost.

There is considerable disagreement among various writers as to how long corn pollen will remain viable after it is shed from the anthers. It has been claimed by some writers that corn pollen will germinate after it has been kept several days—and after it has been kept two weeks.

In 1909 more than a thousand tests were made upon the viability of both pollen and silks. Many combinations in the age of both were made, ranging from 0 to 25 days—fresh pollen on old silks, old pollen on fresh silks, and the intermediate combinations possible. A number of cases proved successful pollenations where pollen was saved (in the paper bags in which it was gathered) till noon of the second day. No reliable pollenation was found in the cases where pollen was used in the afternoon of the day after it was gathered, or when used thereafter. Some of this pollen was gathered in the forenoon and some in the afternoon of the first day. Therefore we are justified in saying that no kernels were obtained when pollen had been stored 30 hours, probably none after 24 hours, and many not that long.

These results are supported by the work of two European investigators who used culture solutions for the purpose of germinating the pollen. Jost[c] thought he secured a weak germination of corn pollen after it had been saved 2 days, but after that, no germination. In more thorough experiments Pfundt[d] was unable to secure germination of corn pollen after it had been saved more than 24 hours. Pfundt submitted the pollen to five treatments: air dried, atmospheric humidity of −90, −60, −30 per cent saturation, and desiccation over sulphuric acid. In no case did he secure germination after the pollen had been stored more than 24 hours.

In breeding work with some plants, advantage may be taken of the fact that the pollen may be viable for weeks and months, but this has not been possible with corn. Putting the immature tassels in cool moist storage might be a feasible method of holding pollen over for a short time to use on a later blooming variety. For ordinary pollenating work and to secure best results corn pollen should be used on the same day on which it is gathered.

From the hand pollenated ears secured in 1909, and upon which the age of the silks was recorded, one case was found in which 13 days had intervened between the appearance of the first silks and the date on which the youngest silks were yet receptive. Other reliable cases ranged between 13 and 0 days, but none above 13 days.

Climatic conditions affect the viability of both pollen and silks, and it is quite possible that longer periods can be obtained than the ones here reported. In the case just mentioned only a few kernels at the top of the ear were obtained. Perfect ears may be secured by one application of fresh pollen or by open pollenation in a period ranging from 2 to 10 days after the silks first appear, all depending upon the variety and the conditions.

The statement by some writers that the silks at the base of the ear appear first, is true only in a broad sense, meaning the lower portion of the ear. Many poorly filled butts and bare tips are found on ears pollenated soon after the first silks appear.

The ear in fig. 1 illustrates the behavior very nicely. The variety to which the ear belongs is a white pop, and in the forenoon of the day on which the first silks appeared on this shoot it was selfed. Eight days later the silks were observed to be long and green, and pollen from a plant in a variety with a yellow endosperm was then

[c] L. Jost, Zur Physiologie des Pollens, Ber. Deut. Bot. Gesell. 23: 504–515, 1905.

[d] Max Pfundt, Der Einfluss der Luftfeuchtigkeit auf die Lebensdauer des Blütenstaubes, Jahrb. wiss. Bot. 47: 1–40, 1909.

applied. The phenomenon known as xenia brought out the difference between the selfed and the hybrid kernels, as is apparent in the figure.

It is significant that the first silks to appear did not come from the extreme base of the ear but slightly above it (as is shown by the irregular band of white kernels). At the end of 8 days the silks at the tip of this ear were not yet developed, as is indicated by the bare cob at the tip of the ear in the figure. This regularity of succession in the appearance of silks is not always apparent in other varieties. We have obtained perfect ears in some instances on the second day after the silks were visible. In other cases the appearance of silks from the cob is very ununiform and irregular patches bare from kernels is the result.

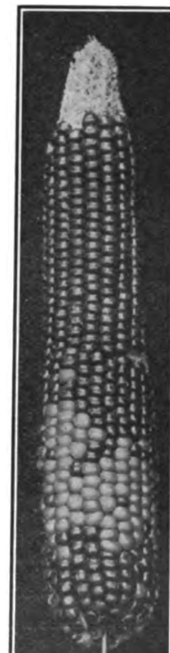


FIG. 1. AN EAR OF PEARL POP-CORN POLLENATED AT TWO DIFFERENT STAGES IN ITS DEVELOPMENT.

This appearance of color (yellow, blue, and red) and starchiness, in the same season in which the hybrid is made, in kernels that when selfed would have developed with the absence of either or both color and starchiness, is of much practical value. Thus if one finds either a starchy or a colored kernel on an ear of white sweet corn, it is a plain case of mixture with another variety. The reciprocals of these (with the exception of some cases of white or yellow or blue) are not noticeable because absence of color and starch is recessive.

For the study of endosperm characters we arranged a case where the pollen of seven individuals of as many different varieties (differing in color and starchiness of the endosperm) was mixed in one composite and applied to the shoot of a white sweet plant. The seeds thus obtained on the same ear were separated into groups according to color and starchiness and were planted the next year, all confirming the accuracy of the classification by the aid of xenia.

In studying the behavior of starchiness, phenomena connected with popping, and various chemical constituents of the kernel, this method is of very great help. Some of the different endosperm characters of varieties of which the pollen may all be mixed in one lot, used on one white sweet ear, and the resulting kernels readily identified that same year by means of xenia are indicated by the following list:

Some possible combinations, all on one ear.

	Endosperm.		*Aleurone layer.*
1.	Colorless	sweet	colorless
2.	Colorless	sweet	red
3.	Colorless	sweet	blue
4.	Yellow	sweet	colorless
5.	Yellow	sweet	red
6.	Yellow	sweet	blue
7.	Colorless	starchy	colorless
8.	Colorless	starchy	red
9.	Colorless	starchy	blue
10.	Yellow	starchy	colorless
11.	Yellow	starchy	red
12.	Yellow	starchy	blue

This list only represents some common cases and might be considerably enlarged.

When the dam produces a number of ears, which is possible where there are a number of ear-bearing suckers, the pollen of a hundred or more varieties may be used all on the same plant and yet permit an accurate separation of the kernels when the corn is mature. The pollen of such a plant might also be used reciprocally on a very large number of other individuals which may differ very widely in many other characters than those discernible only in the endosperm of the kernel. Sufficient pollen may be obtained from one tassel to pollenate many shoots.

It is essential to have a protection of some kind to prevent stray pollen grains falling on the silks while they are being pollenated by hand. The shield is necessary not only during the period of the day when the anthers are shedding pollen, but at all other times because of the pollen which has lodged and is shaken loose while the plant is being pollenated. Some workers protect the silks by not entirely removing the shoot bag and applying pollen from the side opposite to that from which the stray pollen is thought to be coming, but this method is both tedious and unsafe.

An apparatus was constructed for this work as illustrated in fig. 2. The apparatus consisted of an inverted box of very light wood which had been carefully seasoned to prevent checking, all the joins being sealed with glue. A short duck curtain was attached about the base to exclude pollen from the outside. The box was large enough to provide room for the manipulation of the pollen and silk, all but the arms of the operator being on the outside. The side of the curtain inserted between the shoot and the culm was provided with a narrow Ω-shaped opening reinforced with a metal shield sewed in the cloth.

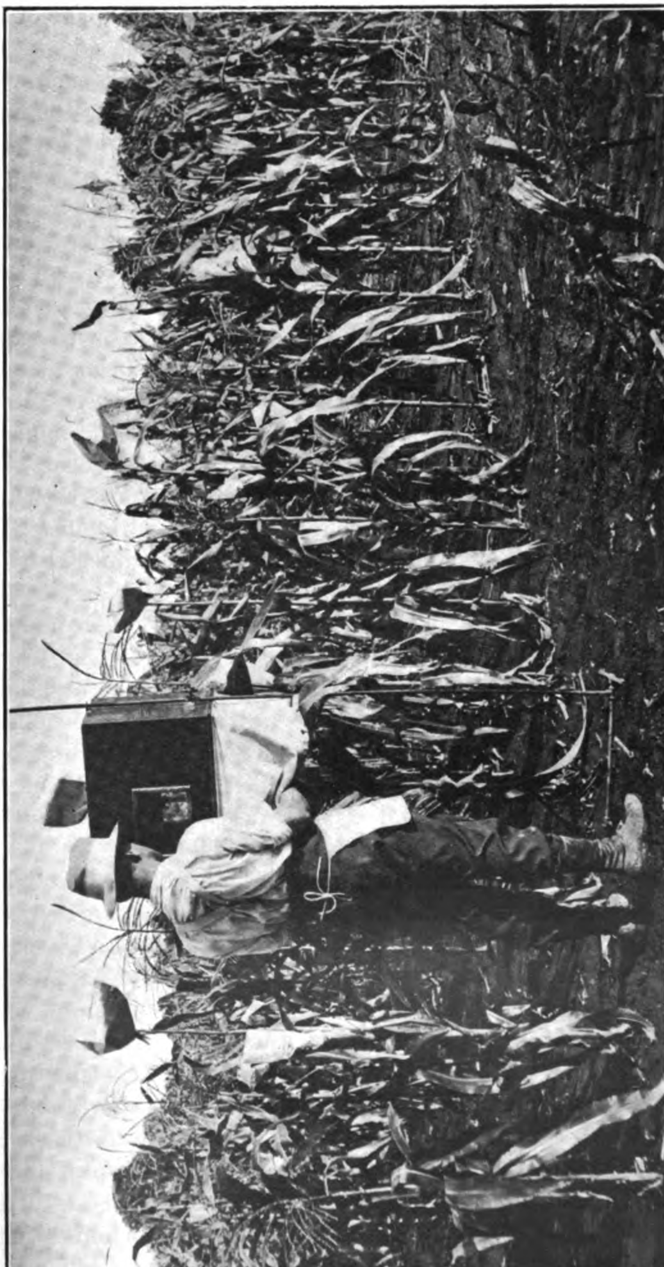


FIG. 2. PROTECTING THE SHOOTS DURING THE OPERATION OF POLLENATING BY HAND.
The method of attaching shoot and tassel bags is also shown.

In the box and just above this opening was inserted a pane of glass to provide light. Glass panes were also inserted in the side opposite and in the top of the box. In this way the operator is enabled to view his work from a number of directions, according to the height of the shoot. The box was readily adjustable to any height on an upright rod mounted on a T base having recurved sharp points to anchor it in the soil and to allow it to be removed readily. These points are long enough to permit straddling a slight ridge which is usually thrown up along a corn row in cultivation.

When the bagged shoot which is ready to be pollenated is under the apparatus the bag is taken off and the silks clipped with scissors at 1 or 2 inches above the tip of the shoot as the bag is being removed. The pollen is applied at once by pouring slowly from the pollen bag. The flow of the pollen is controlled by tapping with the fingers of the disengaged hand upon the bottom and rear of the bag. The scissors used in clipping, and the hands of the operator as well, may be cleaned with the silks which are cut away. In pouring the pollen directly from the bag the silk and pollen are never touched by the hand except by accident, in which case the silks may be cut back farther. There is thus no need of washing the hands in alcohol after each operation, as some workers report doing.

Clipping of silks was done to secure ease in operation, thorough application of pollen, and the prevention of heating after the pollen is applied. When long and tangled silks are pollenated, bare patches on the cob are frequent because the pollen failed to reach the silks on the lower and inner side and also because of the heating which may occur when the mass of silks is large.

The silks or pistils of corn present a stigmatic surface throughout their length and clipping them back does not interfere with the receptivity of the pollen. The silks generally exude sap at the cut surface and yet this is apparently favorable to the germination of the pollen grain although corn pollen soon bursts in pure water. When the husks are stripped back on the shoots which had silks well exposed, and pollen applied to the portions of the silks within the shoot, successful fertilization was effected and fairly good ears were sometimes secured in this way. It was found that as a rule only those silks were receptive which would have appeared very soon after the time at which the husks were opened. Tests of this nature had been made 20 years previously by Kellerman and Swingle,[e] who reported similar results.

[e] Kellerman and Swingle, Receptivity of Corn Silks, 2d Ann. Rep. Kans. Exp. Sta., 1890: 353-355.

It is desirable to have two men working together in pollenating, one man to do the manipulation, the other man to write the notes and attach the labels. Incidentally they can check errors for each other. Very rapid and accurate work is possible and several hundred ordinary pollenations may be accomplished in a day by two men working with the method as outlined.

FIRST GENERATION HYBRIDS OF AMERICAN × CHINESE CORN

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This paper will have to deal with certain data that have been taken in connection with the writer's recent experiments upon the breeding of maize for drouth resistance. It involves observations made upon the F_1 progeny of crosses between strains of western Kansas dent corn, and the unique Chinese corn recently imported from Shanghai by the United States Department of Agriculture. At the outset, the writer must express his appreciation for assistance received from the officials of the Department of Agriculture, and especially to Mr. G. N. Collins, Botanist, of the Office of Crop Acclimatization and Adaptation Investigations, from whom original consignments of Chinese corn were received, and also, this year, two lots of *Zea hirta*, a drouth resistant strain from Mexico.

The superb fundamental work of Correns in 1901 laid the first foundation of our knowledge of the Mendelian behavior of corn. The most thorough biological analysis of maize from the Mendelian standpoint, and the exposition of the chief factors determining its present composition we owe principally to Shull, who, on a suggestion derived by him from the results of Morrow and Gardner in Illinois in 1892, has completed a series of fundamental investigations which have brought out clearly for the first time the true significance of close and cross breeding in this plant.

This knowledge has been further extended by the experiments of Lock in Ceylon, and especially so by the recently published report by East and Hayes, of the results of their work in Connecticut, and by the recent work of Pearl in Maine.

The data thus far available as the result of these recent Mendelian analyses of corn, not only throw a clear light upon the fundamental

facts upon which the breeding of corn actually rests, but also outline plainly the necessary future procedure for the improvement of the cereal.

Thus far, the work of corn improvement, as conducted by the experiment station investigators and practical breeders, has lain strictly along lines of selection of biotypes by the ear-row method, and the subsequent isolation and propagation of the best of these from the standpoint of yield. In consequence of this work, we have in America numerous strains, especially of dent corn, isolated by selection for protein, oil and starch; for height and position of ears, etc.

In this field, the Illinois Experiment Station has done the pioneer work, and still holds today the leading place.

Most of the "corn breeding" done and being done by the American experiment stations, is of the same general nature as the Illinois work, and indeed owes its original inception and impetus to the experiments conducted and the results obtained there.

Some attempts have been made quite recently, to secure a deeper knowledge of the relations of character groups or character units as the case may be, in corn, by means of biometric analysis. This method does not seem to the writer especially promising for breeding purposes in the case of maize. Shull has shown that Indian corn, as found in the ordinary field, is a composition group of extremely complex hybrids, with many allelomorphic pairs concerned, and with all imaginable stages of intercrossing between various heterozygote combinations on the one hand, and other heterozygotes and extractives on the other, and back and forth amongst these latter. It is plain that in such a field of individuals, biometric analysis would have only a quasi value, and would be little likely to indicate anything but somatic or growth correlations. It must be practically an impossibility to discover gametic couplings by the analytical method, in the case of such extraordinary heterozygotes as we have in maize. If, as used to be supposed, maize were simply a congeries of fluctuating variations, analytical correlations would be of great service in the only mode of breeding possible under such a state of affairs, viz: continuous selection. The evident disappointment which the biometric method of analysis has brought to the investigators, so far as the hoped-for assistance in breeding is concerned, is indeed expressed by themselves. See Rietz and Smith, p. 308:

It seems somewhat disappointing that the correlation coefficients differ so widely, as this fact complicates the problem of assessing the influence of the selection of parents in a precise measure of heredity.

And also Ewing (p. 93):

In case of none of the characters discussed above, has the coefficient of correlation with yield been found sufficiently great to be of much value as an index of selection. No single character has shown itself so closely connected with yield of grain as to stand out as a safe guide to the breeder.

and Montgomery (p. 142):

According to the method of study used, there is not a high degree of correlation between various parts of the corn plant. If either high *actual* yield or high relative yield is regarded as indicating a productive type, then none of the plant characters studied can be regarded as closely enough correlated with productiveness to justify the grower who wishes to select for increased yield, in giving much attention to secondary characters of the plant.

It is possible that in some strains of maize quite purely homozygotic in character, if there be any such, biometric analysis will be of direct use in discovering correlations that can be availed of by the breeder. The evidence, however, so far as the commercial strains of corn are concerned, is all against this likelihood.

Any corn plant will of course have fluctuating variations also, but even among these it is immensely difficult, as the writer has shown with wheat (Roberts, 1911), to differentiate the fluctuating variations that arise merely out of the genetic complex, from those somatic changes that soil and climate induce (place variation). Moreover, wheat varieties are possibly more nearly composed of homozygotes than even long and carefully selected strains of corn can be.

With our present knowledge of maize, meager though it is, it seems that the work that will prove fruitful in breeding operations in corn for the future will have to follow the synthetic method of securing desired gametic couplings by crossing, in the light of a previously gained knowledge of the Mendelian structure of the plant. This method, and not the analytical method of endeavoring to find by biometry what gametic couplings do exist, seems most logical in the light of the most recent facts bearing on the constitution of the maize plant.

It was with this method in view that the writer has undertaken the matter of breeding for drouth-resistance in corn. Corn in almost all of its types is as typically a mesophytic plant as can be found. Xerophytism, as it occurs in Kafir corn, durum wheat, or *Medicago arborea,* is all but unknown in the species. Now of course xerophytism or—to coin a more appropriate word "*xeralexis,*"[a] drouth-resistance

[a] *Science* 35:307 (Feb. 23, 1912).

—may depend on many factors in the plant. Certainly the same combination of root, stem and leaf conditions that make for xeralexis in one plant may not be present in another.

What the factors are that determine possible xeralexis in certain strains of corn, are now under investigation, and further discussion of them is reserved for a future paper.

So far as appears at present, two known types of maize are of promise from the standpoint of drouth-resistance, of which the first alone is involved in the crosses under consideration here. This type is the Chinese corn sent to this country from Shanghai by the Rev. J. M. W. Farnham of the American Presbyterian Mission there, and received by the Office of Seed and Plant Introduction of the United States Department of Agriculture in March, 1908. This remarkable strain of *Zea mays* has been fully described by Collins in Bulletin 161 of the Bureau of Plant Industry.

The ample description of the plant as given by Collins need only be referred to here. It suffices to summarize by saying that the Chinese maize is a vigorous, stocky, dwarf type, with the upper four or five internodes very much shortened; the leaves proceeding from these nodes being crowded correspondingly close upon one another. A twisting of the sheaths of these upper leaves, causes the leaf blades to grow on one side of the stalk, instead of alternately on opposite sides of the stem axis. Moreover, these upper leaf blades are erect and upright, much after the fashion of the leaves of Kafir corn; not drooping as in ordinary maize. This habit, combined, with the shortening of the upper internodes, leaves the tassel when mature, standing a foot or so beneath the tops of the overhanging leaf blades (fig. 1). Furthermore, as Collins says:

> As a consequence of the monostichous habit, the top of the plant is curved or scorpoid. The crowding of the leaf blades on one side of the plant, necessarily displaces the top, so that it curves toward the open side of the plant. In the most pronounced cases, the tip of the plant is curved to such an extent that the last leaves pass the perpendicular and bend forward over the tassel with the back of the leaf uppermost (l. c., p. 11).

In the Chinese corn, the silks appear before the ear has emerged from the axil of the lamina, and before the ear within the sheath has grown large enough to be perceptible as a swelling underneath. These characters have been noticed and fully described by Collins. Another character not alluded to by him, is the extraordinary development of the auricles, or lateral outgrowths from the lamina, where

FIG. 1. CHINESE CORN.
Showing general habit of plant, and the protection of the tassel by the leaves.

it joins the sheath of the leaf. These auricles form a sort of screw-like arrangement which facilitates the pollen in its descent to the ear from the overhanging tassel (fig. 2).

It is clear that the whole morphology of the upper part of the plant results in a combination of adaptations for saving pollen and for securing self-pollination. The fan of leaves over and behind the tassel prevents the blowing away of all of the pollen from the tassel underneath. The screw-like arrangement of the broad auricles, secures the accumulation of the pollen in the angles at the bases of the blades; and the early protrusion of the silks into these accumulated masses of pollen insures pollination even in seasons with dry hot winds. The testimony of the sender, Mr. Farnham, indicates that the variety of maize in question, has usually to endure at flowering time pronounced xerophytic conditions, under which American introduced varieties commonly fail.

With respect to the ear characters, the Chinese corn has a small ear 4 or 5 inches long, with small kernels closely packed together. The endosperm is waxy, as Collins describes—not starchy or flinty.

Different strains of Chinese corn exist, differing not in size of kernels but in color of endosperm, whether yellow or non-yellow (white); in aleurone color—whether deep garnet or non-colored. There are therefore strains with white seeds, with yellow seeds and with garnet seeds.

From the American economic standpoint, the Chinese corn would be of value only for silage, fodder, and for the use of the seeds as poultry food. The real value of the strain lies in its vegetative characters.

The writer's experiments, so far as they have gone, involve crosses made in 1910 between Chinese corn and strains of American dent corn that have been grown for a considerable time in Western Kansas, and obtained from the Hays Branch Experiment Station at Hays, Kansas, which is located within the dry-land belt, and possesses a mean annual rainfall of 22.89 inches as compared with 31.12 inches at Manhattan, the seat of the Experiment Station.

It was thought that by using strains already acclimated (whatever that may mean), and having been consciously or unconsciously selected for a period of years in a region of low rainfall, a more promising set of characters for the breeding project in hand, would be found, than could be well supplied elsewhere. The plantings were made in duplicate at Hays and Manhattan.

The Chinese corn consisted of plants grown from some 75 kernels with garnet aleurone—a part of the original Chinese importation

FIG. 2. CHINESE CORN.

Near view, showing the fan of leaves and the broad auricles of the leaf bases, forming a cork-crew-like arrangement which assists in guiding the pollen down to the protruding silks.

furnished by Mr. Collins—to whom the writer's thanks are due for this and other courtesies. In the Manhattan plot there were 18 of the Chinese plants; in the Hays planting 35. The scanty supply of pollen available limited the number of crosses. In all, however, 43 Chinese-American hybrid families were originated in 1910. In this paper, attention will be largely confined to the behavior of the crosses with Pride of Saline, a white dent variety above described.

The F_1 seeds (produced as the immediate result of the current season's pollination) where the Pride of Saline was the seed parent and Chinese the pollen parent, showed a purple xenia—pale—often so pale as to be almost indistinguishable, the general effect of an entire ear being lilac, and not at all the ruby or garnet of the male parent. The starchy endosperm of the female parent, as in Collins' crosses, was dominant to the waxy endosperm of the male.

Two crosses were also secured of Chinese ♀ × Pride of Saline ♂, in which the effect on the F_1 seeds was a change in the aleurone color from garnet to a dull reddish brown. This was uniform and seems to be clearly a xenia effect.

An interesting phenomenon noted in one case in the F_1 seed generation, where the grains of Chinese corn were pollinated from American dent strains, was the immediate increase in the size of the grains over those close pollinated within the Chinese variety.

There can be no question whatever of the correctness of the observation which has been checked by volume determinations of the kernels. The increased growth effect, where it does occur, is undoubted. To what is it due?

Collins has already observed the same phenomenon (Bulletin 161, p. 18), where he says:

> It was apparent from the open pollinated ears of Chinese corn, that the size of the seed was influenced by the nature of the pollen. Seeds which showed by their color and texture the effect of foreign pollen, were in nearly every case distinctly larger than those showing pure Chinese characteristics.

Collins further says:

> Further experiments are needed to determine whether this increase in size is due to the inheritance of the size of a large seeded male parent, or whether the increase is another instance of the increased size of a hybrid over the average of a parent.

I cannot see how the second alternative can be accepted on morphological grounds. The pericarp, or "skin" of the grain, is of course the original ovary wall, plus the two coats of the ovule, grown together

with it into a common structure. The ovule (megasporangium) is also a part of the somatic tissue of the sporophyte (the so-called "maternal" parent).

It is evident that the growth of the "pericarp" (ovary wall and ovule integuments) is a secondary result of fertilization. The pericarp of unfertilized grains grows but little. Now it is clear that the normal growth of the pericarp—and the endosperm—must be determined by different sorts or degrees of "growth impulses"—to use a mere figure of speech—in the case say of the kernels of a dwarf pop-corn and of the huge grains of the Cuzco maize. Grant that these growth tendencies both as to shape and size of the kernels are controlled by hereditary factors, what will happen when the endosperm nucleus of a small-grained sort is fertilized by a male nucleus from a large-grained sort. The result, as Collins and my experiments seem to show, is in some cases at least, the hypertrophic development of the kernels of the small grained race as the immediate result of fertilization.

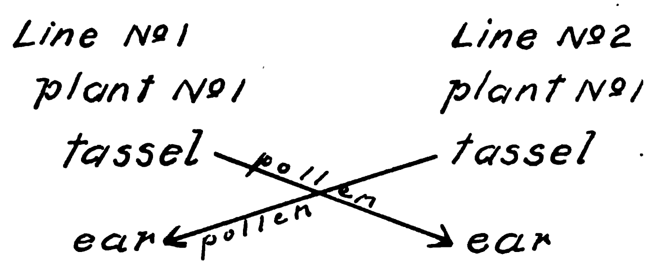
It is inconceivable that the endosperm could grow independently of the pericarp beyond the volume normal for the race to which the endosperm belongs, without the pericarp undergoing a similarly greater growth. Otherwise, when the pericarp reached the maximum for its race, the ever-growing endosperm would split it asunder. Indeed, in one of my Chinese strains, the larger kernels of which were developed upon pollination with pollen from an American dent corn, the pericarp together with the underlying aleurone layer, is split open in a ring around the kernel and at about one-third the distance up from the point of attachment of the kernel.

For the present, the behavior will be discussed, of certain characters in the F_1 generation of a series of seventeen crosses made in 1910 between several Chinese plants and several plants of Pride of Saline, in which the latter were used as the seed parents. Neither the Pride of Saline nor the Chinese had ever been selfed before, and consequently both members of the cross were presumably heterozygous with respect to some characters. The Pride of Saline is a white dent variety, having non-colored pericarp, aleurone and endosperm, and starchy endosperm. The Chinese (male) parent, had non-colored pericarp, garnet aleurone, yellow endosperm and waxy endosperm.

It should be stated that in no case did the parents constitute a known pure line at the time when the crosses were made. The desirability of getting, as soon as possible, results of a practical economic nature, precluded waiting until pure lines should have been secured

by several years of selfing. All of the strains grown for crossing were selfed both in 1910 and 1911 however, so that pure lines are of course in process of making for future work. A record was kept of the characters of each plant used in a cross, and each hybridization constitutes a separate family. At the risk of stating elementary practice, it is perhaps well to emphasize to persons about to engage in Mendelian analyses of corn, the great importance of securing as many inter-plant reciprocals as possible between any two pure lines. By this is meant the employment of members of the *same pair* of individuals for both sides of any given cross. Such a cross may be represented diagrammatically thus:

INTER-PLANT RECIPROCAL



It is rather difficult, especially in small plots, to obtain inter-plant reciprocals in corn. Next in point of accuracy for Mendelian conclusions, are "inter-line" reciprocals, or, simply, "line" reciprocals, in which the reciprocal crossing, while not between identical individuals, is between identical homozygote lines, illustrated on page 378.

The F_1 seeds.—The F_1 seeds throughout the seventeen crosses in which Pride of Saline was the "female" parent, were uniformly lilac in their aleurone color. There was no splashing or blotching as in supposed partly inhibited dominance, and the color was quite uniformly distributed through all the cells of the aleurone layer. The color had a slight suggestion in it of the hypostatic red that gave the garnet color to the Chinese aleurone.

THE F_1 PLANT

The plants of the F_1 generation growing from these seeds showed no dominance of the Chinese characters of short upper internodes (overhanging tassel) or of upright upper leaved. The following tables show the behavior of the seventeen hybrid families of Pride of Saline crosses.

TABLE 1—*F_1 generation of Pride of Saline ♀ × Chinese ♂.*

Hybrid family number.	Character of upper leaves.	Character of tassel.			
		At least partly covered.	Not covered.	Branches loose and spreading.	Branches erect and stiff.
1	Drooping	10	187	187	23
4	Drooping	0	227	212	15
6		23	178	29	172
7	Drooping	5	132	129	8
9	Slightly upright	5	94	33	66
10	Rather upright	2	76	16	62
12[a]		1	30	9	22
12[a]	Not especially upright	0	239	21	218
13	Rather upright	1	69	12	58
14		9	38	39	8
15	Drooping	0	22	21	1
16		9	166	132	43
17	Drooping	0	166	140	26
21	Only occasionally upright	2	206	169	39
22	Slightly upright	1	90	71	20
23	Drooping	0	97	78	19
31		5	363	275	93
32b	Slightly upright	0	48	44	4
	Total	72	2428	1617	897
	Average	4	134	89	49
	Average ratio	1:33		1.8:1	

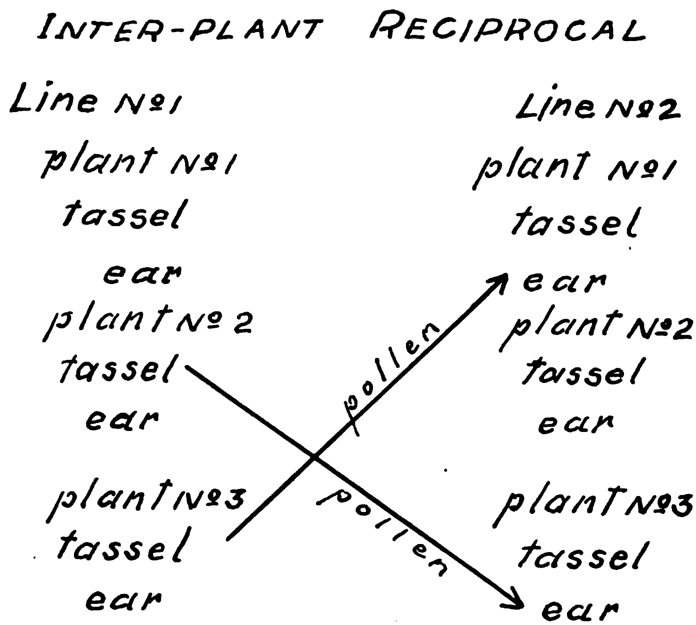
[a] Repeated in another field.

TABLE 2—*F_1 generation. All other American-Chinese hybrids (Pride of Saline ♀ × Chinese ♂ excepted.)*

Hybrid number.	Character of upper leaves.	Character of tassel.			
		At least partly covered.	Not covered.	Branches loose and spreading.	Branches erect and stiff.
2	Rather upright	16	221	30	207
3	Rather upright	10	185	175	20
5	Not generally upright	16	226	178	63
8	Not generally upright	3	182	170	15
11	Not generally upright	1	240	113	128
18	Slightly upright	0	174	159	15
19	Somewhat upright	22	154	158	18
20	Very upright	4	131	109	26
33	Upright	3	41	37	7
34	Upright	10	73	77	6
35	Prevailingly upright	2	87	71	18
35B	Upright	1	129	104	26
36	Upright	9	550	454	105
37	Slightly upright	8	278	194	92
38	Upright	42	399	414	27
39	Upright	7	73	78	2
	Total	154	3142	2521	775
	Average	9	196	157	48
	Average Ratio	1:22		3:1	

The total number of plants counted in the seventeen hybrid families above was 2500, of which 72 had the tassel at least partly covered, and 2428 had the tassel not covered at all—an average of 4 covered and 134 not covered, or a ratio of 1:33. It is evident that no suggestion of Mendelian dominance is derivable from such a relation, and that at least this Chinese character is probably not derived from a single gene.

No very definite general tendency toward uprightness of the upper leaves was observed in most of the Pride of Saline ♀ × Chinese ♂ crosses. In other hybrids between Albright, Wallace, Sherrod's,



Nebraska No. 3, Minn. No. 13, Hays No. 1, Colorado Yellow Dent, and others, taken as "female" parents, with the Chinese as "male" —16 families in all—numbering 3296 plants)—154 had the tassel partly covered and 3142 not covered, the average being 9 and 196 respectively and the average ratio 1:22.

It is evident also here, that, taken as a whole, the shortened upper internodes and other characteristics which produce the overhanging fan of leaves in the Chinese are not derived from a single gene

It would of course have been more exact actually to measure the lengths of all internodes. Lack of time and insufficient help

made this a practical impossibility, and it was only possible to make a careful inspection stalk by stalk, and record the evident result of covered or non-covered tassel. Although apparently a rough mode of determination, it actually is a summation of characters in which one becomes expert in practice, and in which the results probably are not very far from having biometric value.

Now although but few of the Pride of Saline ♀ × Chinese ♂ crosses showed even a strong suggestion of the Chinese plant characters—the ratio being but 1:22, there were higher tendencies in this direction among some of the hybrids, notably in hybrid No. 19 and to a lesser extent in Nos. 2 and 5. Averages are probably of little worth

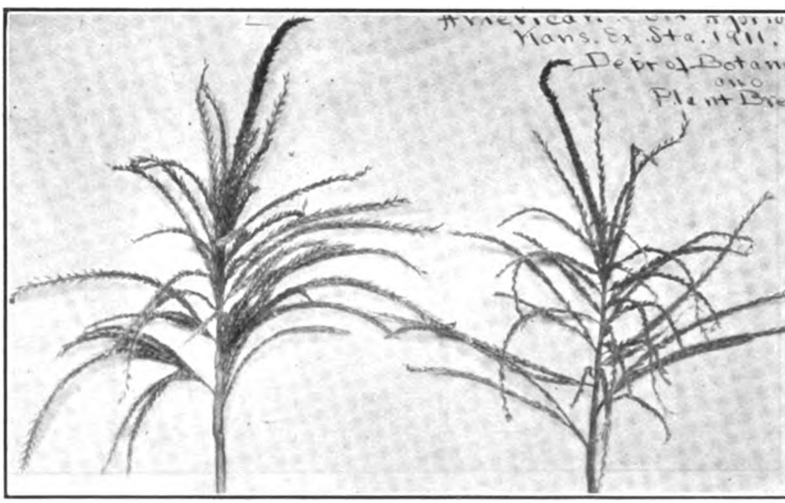


FIG. 3. CHINESE × AMERICAN F_1 HYBRID.
Showing loose open type of tassel.

in cases of this kind, where the material is heterogeneous; yet the mean, as well as the individual variants show that the Pride of Saline × Chinese families, altogether have less tendency toward the emergence of the Chinese plant characters than do the most of the other hybrid families. One Pride of Saline hybrid family only, No. 19. shows a ratio of 1 covered tassel in 7—a ratio as high as is found in two of the other hybrid families outside the Pride of Saline stock.

It would be useless to analyze such data further. The only reliable evidence can be gained by breeding.

A strong tendency exists in the hybrid families toward a certain amount of definiteness in the type of tassel in the F_1 generation.

In general the tassel is either loose and open, with the lateral branches horizontal or drooping (fig. 3) or dense and strict, with the lateral branches erect, and forming an acute angle with the central axis (fig. 4).

The general tendency among the great majority of the hybrid families is toward the loose, open, spreading type of tassel.

Here also there is nothing that can be called a prevailing dominance of type even among the Pride of Saline ♀ × Chinese ♂ families, where the ratio of loose to strict tassels varies from 1:47 to 1:2.

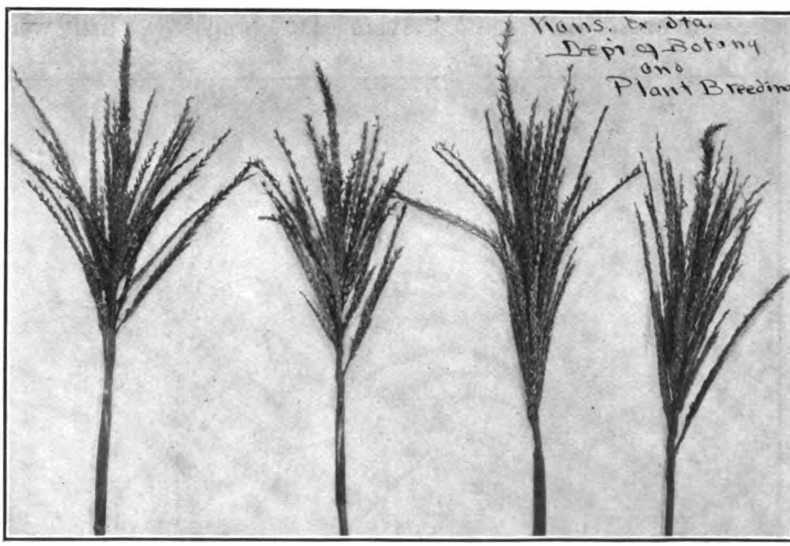


FIG. 4. CHINESE × AMERICAN F_1 HYBRID.
Showing strict erect type of tassel.

The fact that there is an average ratio 1.8 to 1 for the Pride of Saline hybrids, and of 3:1 for the others is simply of statistical value of course in an F_1 generation.

No correlation appears to exist between upright tassel branches and upright leaves, as the following table sufficiently indicates, in which all of the hybrids having any marked tendency toward upright leaves are included.

No tendency was observed toward the appearance as a dominant character in the F_1 generation, of the almost perfoliate leaf condition caused by the encircling of the stem by the broad auricles of the laminae—a marked Chinese characteristic (fig. 2).

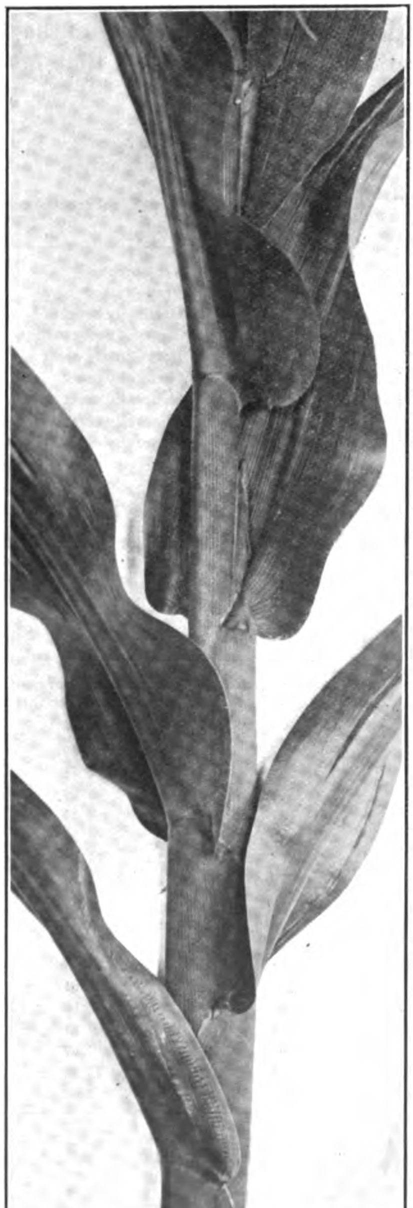


FIG. 5. CHINESE × AMERICAN F_1 HYBRID.
Showing broad leaf bases or "auricles."

Some individual hybrids show this strongly (fig. 5), but there is no general tendency, and the occurrence of the perfoliate condition in the F_1 generation is even rarer than that of the other Chinese characters.

TABLE 3.

Table.	Hybrid family number.	Degree of leaf erectness.	Tassel habit, ratio loose : strict.
1	6	Very erect	1 : 6
2	20	Very erect	4 : 1
2	33	Generally erect	5 : 1
2	34	Generally erect	13 : 1
2	35	Prevailingly erect	4 : 1
2	35B	Generally erect	4 : 1
2	36	Generally erect	4 : 1
2	38	Generally erect	15 : 1
2	39	Generally erect	39 : 1

YIELD.—In respect to the matter of yield the data confirm Shull's results and those of other investigators. The following tables give the details.

TABLE 4.—*Yield of plants of F_1 generation. Pride of Saline ♀ × Chinese ♂.*

Hybrid number.	Number of plants.	Total weight of ears.	Average yield per plant.
		kilos.	*grams.*
1	197	13.60	69
4	227	17.18	75
6	201	9.29	46
7	137	9.26	67
9	99	6.22	62
10	78	13.16	168
12	279	9.11	32
13	70	4.40	62
14	47	4.33	92
15	22	1.61	73
16	175	13.48	77
17	166	14.08	84
21	208	16.96	81
22	91	6.51	71
23	97	7.67	79
31	368	30.95	84
32B	48	5.07	105
Average weight of ears per plant (grams)			78

TABLE 5.—*Yield of plants of F_1 generation. All other American-Chinese hybrid families.*

Hybrid family number.	Number of plants.	Total weight of ears.	Average yield.
		kilos.	*grams.*
2	237	14.46	61
3	195	17.52	89
5	241	15.19	63
8	185	11.30	61
11	241	9.95	41
18	174	12.61	72
19	176	10.59	60
20	135	6.65	49
33	44	4.96	112
34	83	7.98	96
35A	89	7.77	87
35B	130	11.39	87
36	559	38.63	68
37	286	11.28	39
38	441	16.72	37
39	80	9.99	124
Average weight of ears per plant (grams)...................................			71

TABLE 6.—*Yield of commercial strains of dent maize, 1911. Selfed in 1910.*

Number.	Number of plants.	Total weight of ears.	Average yield per plant.	Number.	Number of plants.	Total weight of ears.	Average yield per plant.
		kilos.	*grams.*			*kilos.*	*grams.*
3	168	2.65	15	41	126	6.39	50
4A	105	1.79	17	42	252	5.65	22
4B	84	1.28	15	43	126	1.09	8
5A	168	4.18	29	44	126	4.15	33
5B	62	3.18	61	45	42	0.44	10
6	168	6.37	38	46	128	4.81	37
7	42	1.02	24	47	126	1.08	8
8	42	1.20	28	48	126	2.05	16
12	420	11.67	27	49	84	4.91	5
13	146	6.10	41	50	126	4.93	39
14	168	2.00	12	52	168	1.09	6
15	294	7.62	26	55	42	0.16	3
16	84	0.70	8	56	42	0.14	3
17	210	1.14	5	57	126	0.70	5
18	84	1.60	13	58	84	0.32	4
19	126	2.26	18	64	168	1.76	10
20	126	3.08	24	74	84	3.04	37
21	126	2.80	16	75	84	1.00	12
22	42	0.60	14	77	84	0.83	9
23	42	0.44	10	81	84	0.39	4
24	42	0.44	10	85	42	0.44	10
25	126	1.82	14				
39	168	5.23	31	Average weight of ears per plant (grams), 18			
40	84	1.88	22				

From the above tables it is seen that the seventeen Pride of Saline hybrid families averaged in weight of ears 78 grams per plant; the other sixteen averaged 71 grams per plant, while the twenty-four pure lines (selfed one year), averaged 18 grams per plant. In other words the average yield of the cross fertilized families was 76 per cent higher than that of the self fertilized families.

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THE INHERITANCE OF CERTAIN "ABNORMALITIES" IN MAIZE[a]

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Some of the abnormalities considered in this paper seem to have no effect on the yield or quality of grain while others result in greatly decreased yields and some even cause the total destruction of the plants. Between these extremes there are many grades of injuriousness. None of the characters listed here as abnormalities are actually known to increase the yield or improve the quality of the crop, though some of them, liguleless leaf for instance, may possibly be found to lessen transpiration and in that way enable a variety possessing it to withstand drouth better than sorts with normal leaves.

A classification that separates characters into *normal* and *abnormal* is not entirely satisfactory. If we are to consider abnormal any character that is out of the ordinary, we are likely to find characters that in one type of corn are perfectly normal, but in another type decidedly abnormal. The tendency to produce numerous tillers, 7 or 8 per plant, or to produce 4 or 5 ears per stalk, characters common in some very small varieties of pop corn, would doubtless be considered abnormal by one unacquainted with such sorts, particularly if those tendencies should crop out in a field of some large dent corn. The characters listed here as abnormal are all doubtless the resultants of inherited tendencies on the one hand and environmental influences on the other, exactly as are so-called normal characters. It is scarcely conceivable that there is any fundamental difference between the two catagories. Some characters of maize are, however, commonly spoken of as abnormalities. Several such are discussed here.

Dwarf hermaphrodites.—In 1910 there were found in 3 families of corn certain dwarf plants that differed from the normal tall plants of the same families not only in stature but also in having short and relatively broad leaves, thick, little branched tassel, and small ears which usually ended in a thick unbranched tassel and always had well developed stamens throughout (see figs. 1 and 2). Moreover, the anthers of the tassels did not shed pollen normally but sufficient

[a] Some of the tests reported here were conducted at the Bussey Institution of Harvard University during 1911. I am indebted to that institution and to Dr. E. M. East particularly for placing at my disposal room in the greenhouses and gardens and for photographic and other facilities for laboratory and field work. The remainder of the work was done at the Nebraska Agricultural Experiment station with funds of that institution.

pollen was obtained for selfing a few ears by scraping it from individual anthers with the point of a knife. The three 1909 parent plants of these three 1910 families were normal with respect to all these characters, and the 1910 progenies contained slightly over 4 normal tall plants to 1 dwarf hermaphrodite—exactly 107 to 25. The counts were made after the plants had reached their full size. Some of the dwarfs may have perished while young.

The self-fertilized seed of the dwarf plants, though apparently well developed, germinated very poorly or else the plants died while very

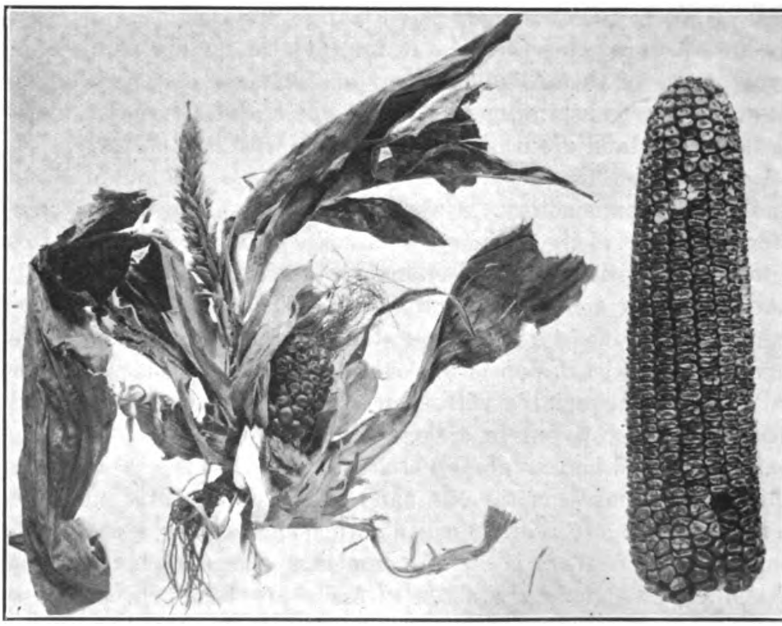

FIG. 1. AN ENTIRE PLANT OF THE SMALLEST TYPE OF DWARF HERMAPHRODITIC CORN, AND AN EAR OF NORMAL SIZE.

The latter is a first-generation cross of a dwarf hermaphrodite of a somewhat larger type than the one shown here with a plant of normal size.

young, only 9 plants having matured in 1911 from 94 seeds planted. All of these 9 plants were dwarf hermaphrodites like those of the preceding year, suggesting that the type breeds true. The seeds of several ears that resulted from the application of pollen of various tall strains of corn, to the silks of the 1910 dwarfs germinated well and produced in every case perfectly normal plants with well developed ears—310 plants in all from seven such crosses—showing that the normal type is fully dominant. Three of the normal plants of

these 1910 families when selfed, yielded only normal plants in 1911 while three others yielded both normal and dwarf plants, the respective numbers in these progenies being 58 tall and 11 dwarf. (Again the records were not made until after the plants had completed their growth so that it cannot be known whether the numbers reported represent correctly the numbers of the two classes at the time of germination.) Finally, some of the first generation crosses of 1911—normal plants as noted above—were selfed and their progenies grown

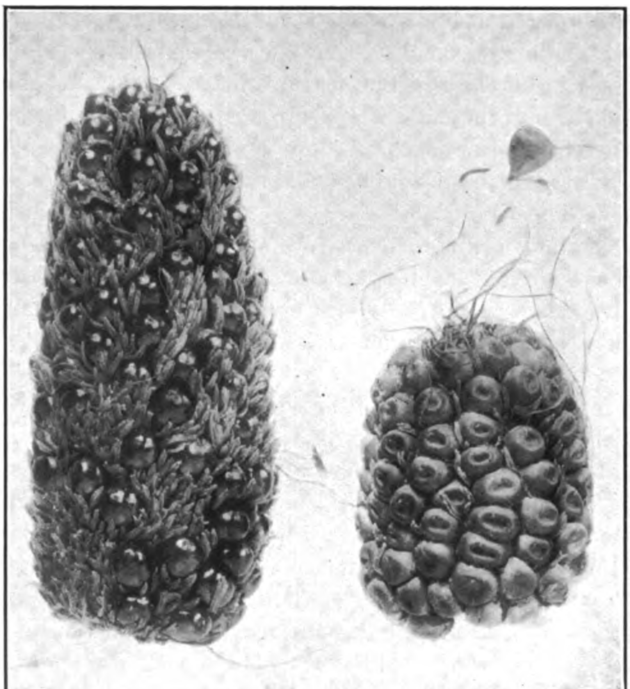

FIG. 2. EARS OF DWARF HERMAPHRODITES SHOWING STAMENS THROUGHOUT (NATURAL SIZE).

in the greenhouse the present winter. These plants were grown thickly in shallow pans to the age of three or four weeks. While it was obviously impossible to tell from the seedlings whether they would later have abnormal ears and tassels, the segregation into tall plants with long comparatively narrow leaves and dwarf plants with short, broad leaves was so distinct that it could not be mistaken (see fig. 3). Every one of these progenies, 17 in all, contained both types of plants, the total number of individuals being 714, of which 528 were tall and 200 dwarf. This near approach to the simple Men-

delian ratio of 3 : 1 in case of the families germinated under the favorable conditions in-doors suggests that the deficiency of dwarfs found in field-grown hybrid families and the small number of plants in pure dwarf families (as indicated by counts after the plants had completed their growth) are due to poor germination or early death of dwarfs under field conditions rather than to departure from ordinary Mendelian behavior.

These results indicate that the abnormality in question is a recessive character, or group of correlated characters, and that therefore it may be transmitted through perfectly normal, productive plants which are hybrid for the abnormality. In fact, it must under ordinary field conditions be thus transmitted, if transmitted at all, since the dwarfs themselves, even if they live to mature, shed almost no pollen and produce such very inferior ears that they would under no circumstances be selected for seed and probably would never even be harvested. How general this defective type is cannot be said. It has been reported in 4 or 5 distinct strains of corn from three widely separated localities.[b] The fact that such dwarf plants as these are not commonly noticed in fields does not prove the absence of the abnormality from the strain in question. Under ordinary field conditions they would almost always be overlooked.

Yellow leaves.—In a small plat of silage corn grown at the Nebraska Experiment Station in 1910 there were found twenty-four plants of a distinctly light yellowish-green color resembling somewhat the so-called "golden" varieties of various shrubs alleged to have value as ornamentals. As indicated by their color these plants doubtless possessed a considerable quantity of chlorophyll since they grew to maturity and were of normal height though rather slender. All of them produced pollen in abundance, apparently as much as normal plants. Only four of the twenty-four, however, showed any indication of silks and not one of the four produced an ear. They were therefore practically barren. Obviously no self-pollinated ears were obtained. A similar yellow plant found in a field of another variety of corn did, however, produce a fairly good ear by open pollination. Seed from this ear planted in 1911 resulted in a considerable percentage of yellow plants, most of which produced no ears or only very poor ones. Pollen from some of the barren yellow plants of 1910 was applied to silks of green plants of two other strains and the resulting cross-bred plants of 1911 were all of a fully green color and were

[b] See East and Hayes, Bulletin 167, Conn. Agr. Exp. Sta., 1911; Montgomery, Pop. Sci. Mon., Oct., 1911; and Emerson 24th Ann. Rpt., Neb. Agr. Exp. Sta., 1911.

FIG. 3. NORMAL AND DWARF SEEDLINGS FROM A SELF-POLLINATED EAR OF A HETEROZYGOUS NORMAL PLANT.

The tall seedlings were removed from one side of the flat and the dwarf ones from the other side shortly before the photograph was taken.

normal in productiveness. The total number of such plants was 137, a sufficient number to show the completely recessive nature of this abnormality. No second generation has been grown. The most interesting cross-bred plants of this yellow-leaved corn came from a small ear of the dwarf-hermaphrodite corn discussed above, pollinated from a barren yellow plant. Notwithstanding the fact that both parent plants were worthless from a corn producer's standpoint—one of them having produced no ear and the other only very inferior ones—their hybrid progeny was nevertheless one of the most productive lots grown in 1911, having yielded at the rate of nearly 40 bushels per acre from a poor stand in a year of unprecedented drouth (see fig. 4). The plants inherited normal size from the yellow-leaved parent and full green color from the dwarf parent.

This yellow-leaved type of corn is more likely to persist in a commercial strain than the dwarf type because of the abundant production of pollen from the pure yellow plants though they may produce no corn that would ever be selected for seed. It of course has the same chance as the dwarf type to persist in the hybrid condition in perfectly normal, productive plants.

White seedlings.—It is not uncommon to find numerous pure white seedlings in a field of corn. Such plants owing to their inability to make food for themselves, always die as soon as they exhaust the food stored in the seed (see fig. 5). Such a total loss of power to produce chlorophyll in a certain percentage of the seedlings is a characteristic of some stocks of corn. Five such stocks, all apparently unrelated, have been included in my cultures. The results obtained from a study of them are presented in detail in a paper to be published in the twenty-fifth annual report of the Nebraska Agricultural Experiment Station.

When all of my corn families that have shown white seedlings (a total of 42) are lumped together, they are found to have contained a total of 1903 plants, 1457 of which were green (including nine striped plants) and 446 of which were white. This is not far from the three-to-one ratio expected when dealing with a recessive Mendelian character. While the nature of this abnormality makes it impossible to produce a true-breeding white strain that can be crossed with pure green strains, there are, nevertheless ways of testing the method of its inheritance. If whiteness is a pure recessive, the green plants in any family in which white seedlings occur must be of two sorts, one homozygous green, producing nothing but green offspring, the other heterozygous green, yielding on self-pollination about 3 green

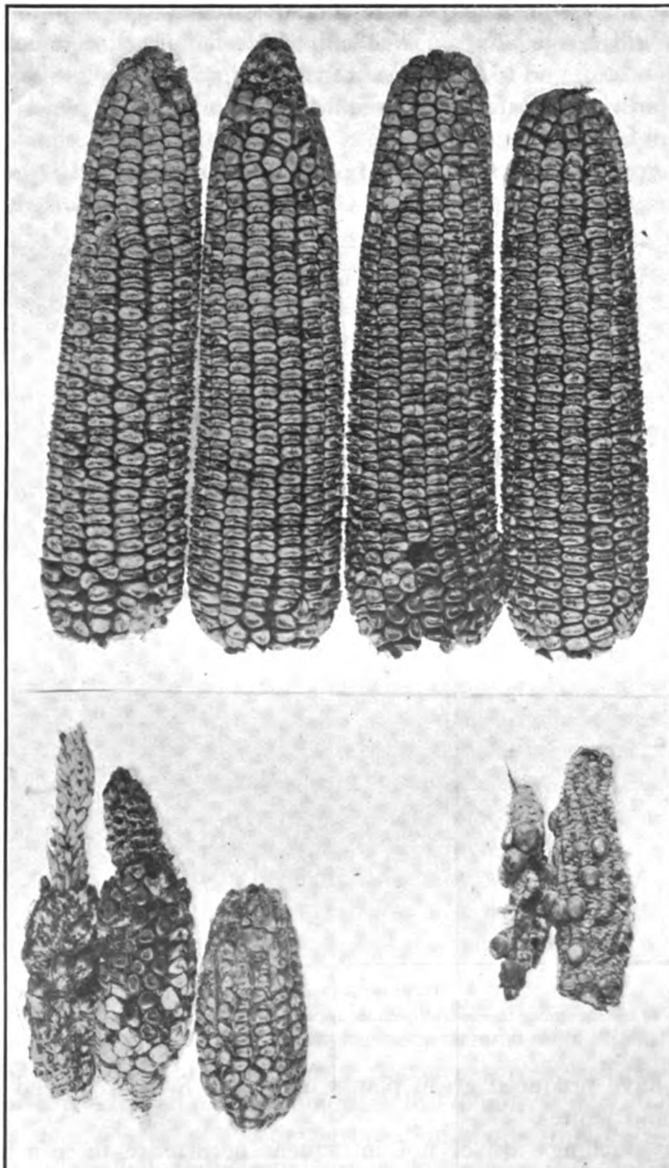

FIG. 4. FOUR TYPICAL FIRST-GENERATION EARS PRODUCED BY CROSSING A WORTHLESS DWARF HERMAPHRODITE.

They bear ears like the three shown at the left of the cut, with pollen from a tall yellow-leaved plant, a type which rarely produces anything better than the two "ears" shown at the right.

seedlings to 1 white one. There should, of course, be 1 pure green to 2 hybrid green plants. Of 43 plants tested from such families, 15 have been found to breed true to the green color and 28 have produced both green and white seedlings. Similarly of plants from all-green families resulting from a cross of pure green plants with hybrid green ones, half should breed true green and half produce both green and white seedlings. Of 17 plants tested from such fam-

FIG. 5. HETEROZYGOUS GREEN PLANTS.

If selfed or crossed among themselves, produce approximately three green seedlings to one white one. The latter die within two or three weeks because they cannot produce food for themselves.

ilies, 9 have produced green plants only, and 8 have yielded both greens and whites.

White seedlings are of not infrequent occurrence in corn fields. Whether this is a more common abnormality than dwarfness, yellow leaves, etc., or is merely more commonly seen on account of its conspicuousness, cannot be said. While it apparently always results in the death of the plants showing it, it is really not much worse from an economic standpoint than dwarfness or yellow leaves.

Erect leaves.—In another paper, to be published in the twenty-fifth annual report of the Nebraska Agricultural Experiment Station, I have described a very peculiar erect leaf habit due to the absence of the small, triangular, leathery connection between the leaf blade and leaf sheath, called the auricle. This, in my corn, is accompanied in almost all cases by the absence of the ligule, a membraneous projection of the sheath above the base of the blade. The peculiarity results in a lessening of the exposed leaf surface and should on that account lessen water loss from the plant. It may also impair the plant's ability to produce carbohydrate food. The enclosure of the tassel by the upper leaves of the plant causes the pollen to spoil in wet weather but may be found beneficial as a protection against too severe drying of the pollen in certain climates (see fig. 6). Erect leaves associated with a one-sided (monostichous) arrangement of the upper leaves, not uncommon in this and other types of corn (see Collins, Bulletin 161, Bureau of Plant Industry, U. S. Dept. Agr.) whereby the tassel is enclosed except on one side, is less likely to cause rotting of the pollen while still presumably affording considerable protection against drying. Stocks of corn not lacking the auricle may also have fairly erect or ascending leaves due to the size and stiffness of the mid-rib. This condition does not result in a lessened exposure of the leaves and their stiffness makes them more easily torn or broken by the wind. The non-auriculate leaf always has the lower part of its blade wrapped more or less closely about the stalk much as the sheath is, and the upper part of the blade free. The abnormality does not seem to lessen the production of grain and in this respect therefore is quite unlike the forms already discussed. This leaf type has not been reported before for corn so far as I am aware. Like many other abnormalities, however, it may have been in existence for a long time though unobserved, and may even now be more or less common.

In inheritance, this peculiarity is a simple Mendelian recessive as are the other abnormalities so far considered. Since it was first discovered in 1910, I have grown progenies of six self-pollinated non-auriculate leaved plants amounting to 175 individuals, all lacking the auricle. A total of 103 first generation plants from four crosses between abnormal and normal leaved types have all had normal leaves. In the second generation of such crosses 672 normal and 221 abnormal leaved individuals have appeared. My results also indicate that this peculiarity is not correlated with such other abnormalities as dwarfness, white seedlings, etc.

Irregular kernel rows.—It has been suggested by East and Hayes (Conn. Agr. Expt. Sta. Bulletin 167) that the irregular arrangement of kernels on the cob is a dominant Mendelian character, though perhaps not a simple one. What little evidence I have seems to indicate on the contrary that the arrangement of grains in regular rows is perhaps the dominant character. The only records I have bearing upon the inheritance of this character are from a hybrid between a dwarf pop corn with "zigzag" rice-pointed grains and a large dent corn with fairly straight rows. The arrangement of kernels on ears of the parent races and of first and second generation plants of the cross is shown below. All the plants from which these records were made were grown in adjoining rows at the Nebraska Experiment Station during the summer of 1911. One well developed ear, usually the upper one, was taken from each plant and from these ears alone the records were made. All ears in which the rows could be easily followed from one end to the other were classed as regular, those in which the rows could be followed readily for a considerable distance from one end of the ear, but in which no rows could be traced at the other end, were classed as intermediate, and finally those in which the grains had a zigzag arrangement throughout were classed as irregular. Since the number of plants representing the several generations differ widely, the records are here given in approximate percentages to facilitate comparison.

	Number of plants.	Per cent regular.	Per cent intermediate.	Per cent irregular.
Dent corn parent	29	90	10	
Pop corn parent	67		13	87
First hybrid generation	59	85	10	5
Second hybrid generation	344	63	20	17

If it were not for the 5 per cent irregular-rowed ears in the first hybrid generation, the results might well be interpreted as due to simple Mendelian dominance of the regular-rowed condition. The ears of intermediate type would then have to be regarded as non-inherited fluctuations as suggested by East and Hayes. It may be that even the fully irregular ears of the first hybrid generation are extreme cases of fluctuation. It is not worth while to prolong this discussion, however, because no detailed record as to regularity of rows was made in case of the earlier generations of the parent stocks and it cannot be shown, therefore, that the parent plants were fully

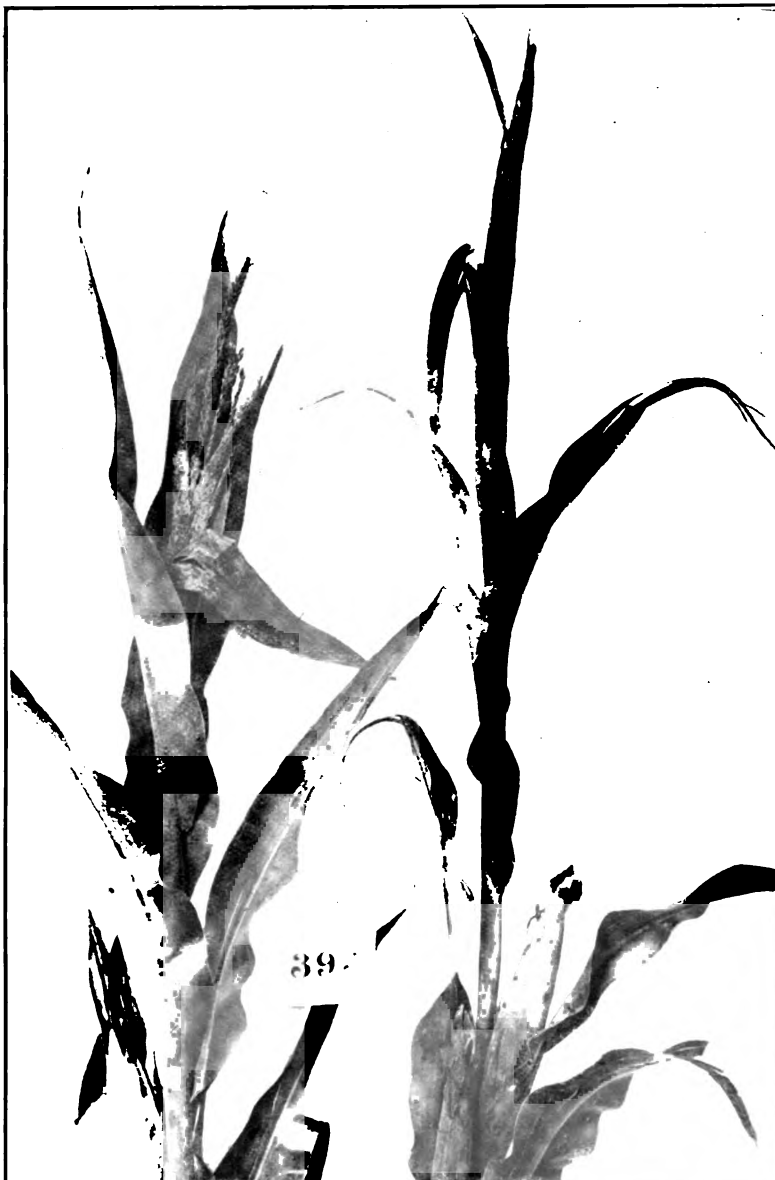

FIG. 6. ERECT LEAF HABIT DUE TO THE ABSENCE OF LEAF AURICLES.

Wet weather often spoils much of the pollen as is shown by the plant at the left of the cut, a leaf of which has been pulled away from the tassel.

homozygous for the character concerned, though they came from self-pollinated strains. The indications of these results, that irregularity in rows is a recessive character, accords with the experience of Halstead with crosses of Country Gentlemen sweet corn and various straight rowed sorts (see Rept. Bot. Dept., N. J. Agr. Expt. Sta., 1906).

Other recessive abnormalities.—In addition to the five abnormalities considered in detail above, all of which are recessive, I have very incomplete records of the behavior of a few others that are apparently recessive. In none of these cases are my records sufficient to make it worth while to present them in detail. I have two strains of corn that show a noticeable inability to stand erect in strong winds, probably due to poor rooting. First generation crosses between these and normal strains stand erect as well as any corn I have. In case of one small second generation a few of the plants blew over while the remainder stood up well.

Several of my families of pop corn, all more or less closely related, have a peculiar zigzag stalk above the upper ear accompanied by a shortening of the internodes at the same place. Such plants seem at first to have broad flat stems but this appearance is due to the spreading apart of the over-lapping leaf sheaths by the abrupt crooks in the stalk. Sometimes the sheaths are shoved aside so far that they no longer clasp the stalk and are therefore unable to give their customary mechanical support to the rapidly elongating and therefore not very rigid stalk and as a consequence of this the whole upper part of the stalk breaks off above the ear. Crosses of this type of corn with normal types have given only normal plants in the first generation.

Dominant abnormalities.—Fasciated, bifurcated, and branched ears are classed as Mendelian dominants by East and Hayes. The only one of these that I have had to do with is fasciated ears. The degree of fasciation varies much even between the different ears of a single plant, some ears being very broad at the tip while others are only slightly flattened. Notwithstanding the probability that this pronounced variation within a strain is mere fluctuation, I am of the opinion that different degrees of fasciation may be inherited. I have one stock in which nearly all the ears show an extreme type of fasciation not seen at all in other families. Of course this difference may not be due to the presence of distinct factors for fasciation in the different strains but merely to a different resultant from the

interaction between a single fasciation factor and other diverse characters of the different strains.

Fasciated ears from families that produce both fasciated and normal ears breed true fasciated or produce a large percentage of fasciated ears along with some normal ones, thus indicating that some plants with fasciated ears are homozygous and others heterozygous. From a 1910 family of pop corn that contained both types of ears, four fasciated ears were used as parents of 1911 families. Two of these produced 18 and 46 plants respectively, all with strongly fasciated ears. Of the other two families one had 12 plants with ears more or less fasciated and three with ears that were apparently perfectly normal. The fourth family, consisting of 28 plants, had some ears that were strongly fasciated, some that were apparently normal, and about all grades between these extremes, making definite classification almost impossible. A 1911 family of dent corn grown from a fasciated ear of the year before contained 32 plants with more or less fasciated ears and 35 plants with ears apparently normal, though some of the latter may have been slightly flattened. While these results suggest that fasciation is dominant, they also indicate that it is not a simple character.

No cross between a pure fasciated strain and a pure normal one has been studied. The heterozygous fasciated plant, which when selfed produced the dent corn family noted above, was crossed with a plant of a family of normal 8-rowed flint corn. The first generation consisted of 63 plants every ear of which was apparently perfectly normal. I do not remember ever to have seen a fasciated ear in any type of corn with so few as twelve rows. The apparent dominance of normal over fasciated ears in this cross may perhaps be due in some way to the fact that it was largely made up of 12-rowed ears. If the normal eared plant used in the cross had been of a family having a larger number of rows, the results might have been different. But all that can be said now is that this case must be given further study.

Some strains of pop corn often have staminate spikelets intermingled with the ordinary pistillate flowers of the ears. Sometimes the staminate flowers are clustered together at one side of the ear, or may extend entirely around the ear near the middle or between that and the tip end, thus separating the ear into two parts, the connection resembling the central spike of a tassel. Often the staminate spikelets are interspread with pistillate spikelets near the tip of the ear, which then tapers rapidly. Not uncommonly one flower of a spikelet

may be pistillate and the other staminate. Finally the ear may be normal except that it ends in a club-shaped tassel This intermixture of staminate and pistillate flowers on the same ear is not to be confused with the hermaphrodite ears of the dwarf corn discussed earlier in this paper, for in the latter each grain has associated with it from three to six stamens and the glumes are of the roundish cob type, while in the case here considered the stamens are limited to the staminate flowers and are always associated with rather slender, pointed, tassel-type glumes.

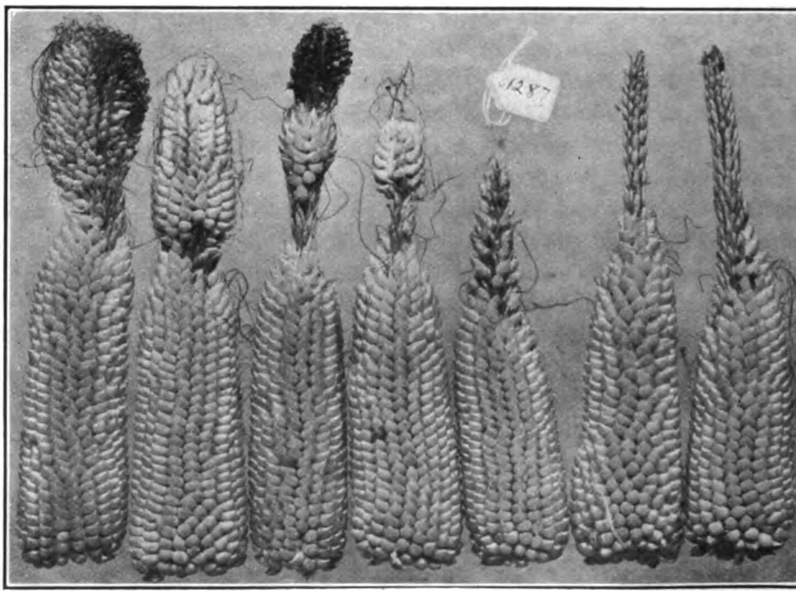

FIG. 7. INTERRUPTED EARS.

Representatives of a first generation of a cross of a normal-eared strain of pop corn with a strain having interrupted ears.

The only indication I have of the dominant nature of this abnormality is derived from a single cross between a plant having it and a plant from a family all individuals of which were apparently normal. Every ear of the first generation was interrupted to a greater or less degree by staminate flowers (see fig. 7).

Various unclassified abnormalities.—There are several other abnormalities which are certainly inherited since they always occur in all or in a considerable number of the plants of certain families, while they are not seen in other families. As yet, however, not enough is known regarding the manner of their inheritance to say even whether

they are dominant or recessive characters. It will not be worth while to do more than mention them here.

In most varieties of corn the silks appear after the ear shoot has pushed well out of the sheath, and usually a day or two after the pollen has begun to shed. From two varieties of pop corn, Tom Thumb and White Rice, I now have strains in which the silks push up out of the sheath considerably in advance of the ear shoot and appear from one to four days before any pollen is shed. It seems probable that in corn protogynous habit and the appearance of the silks directly from the sheath are both the same thing—a precocious development of the silks.

In a single family of corn grown from a cross of sweet corn and pop corn made some years ago, the tassels of every plant were held in a position varying from horizontal to fully pendant. The peculiarity is due to the formation just beneath the tassel of one or more small ears, or sometimes of a small tassel enclosed in husks, which push the stalk out of its supporting leaf sheaths. These accessory ears appear several nodes above the upper one of the normal ears and at about the same time as the latter. The reason why they crowd the stalk to one side and even out of its leaf sheath, while the normal ears borne lower on the stalk do not, is doubtless due to the fact that the stalk is elongating rapidly and is therefore not so rigid just beneath the tassel as it is lower down at the time the ears develop.

A strain of Red Rice pop corn in my cultures of 1910 and 1911 had opposite instead of alternate leaves for a few nodes above the ear and whorled leaves just beneath the tassel, usually accompanied by considerable shortening of the upper internodes and even of the tassel itself. This results in a partial enclosure of the tassel in the clustered upper leaf sheaths and a consequent decay of much of the pollen.

Other abnormalities of considerable interest that have occurred in my cultures are forms of sterility in varying degrees. In some cases almost no pollen is produced though the tassels, anthers and the plant in general are otherwise normal. In other cases both ears and tassels are greatly reduced and in the final stages consist of mere stems absolutely bare of flowers.

GETTING RID OF ABNORMALITIES IN CORN

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COMBINATIONS OF ABNORMALITIES

In another paper I have discussed the inheritance of several abnormalities in corn. It is not to be supposed of course, that they include all the abnormalities present in corn, though the number considered in my paper is over a dozen. While some of my stocks of corn are free from any character that would likely be classed as abnormal, other stocks have two or three pronounced abnormalities. In the latter case the percentage of perfectly normal plants is of course reduced much below what it would be if only a single abnormality were concerned. For instance, certain of my families produce both dwarf hermaphrodites and white seedlings. Of 269 individuals in these families only 150 were normal, i.e., both tall and green, while the other 119 were abnormal, 40 of them being dwarf greens, 58 tall whites, and 21 dwarf whites. Other families containing in all 301 plants had only 159 that were normal in height and in leaf form, while the other 142 were abnormal, 63 of these having liguleless leaves, 58 being dwarf, and 21 both dwarf and liguleless. Again in other families, totaling 113 individuals, 58 were normal and 55 abnormal, there being of the latter 15 that were merely liguleless, 16 dwarf, and 8 white, 7 that were both dwarf and liguleless, 4 white and liguleless, and 4 dwarf and white, and finally 1 that was dwarf, white and liguleless. The theoretical proportion of abnormal plants in the progeny of any individual that is heterozygous for recessive abnormalities and that is self-pollinated or cross pollinated by a plant like itself are 25 per cent where one abnormality is concerned, 44 per cent for two abnormalities, 58 for three, 68 for four, 76 for five, and so on up to 94 per cent if ten abnormalities are present at once. Under the same conditions if dominant instead of recessive abnormalities are concerned, the percentages of abnormal individuals are 75 for one abnormality, 94 for two, 98 for three, and so on to 99.9 per cent if five abnormalities are present in the same stock.

NATURAL ELIMINATION OF ABNORMALITIES

From the fact as illustrated above that dominant abnormalities show in a much larger percentage of the individuals of an affected

stock than recessive abnormalities do, it might be supposed that they would be more difficult to eliminate. This, however, does not follow, and, under certain circumstances, in fact the opposite is true. In case of an abnormality that does not influence the health or productiveness of affected plants, there would of course be no natural tendency either to increase or decrease in relative numbers whether the abnormality were dominant or recessive. The dominant abnormality, fasciation of ears, and the recessive one, irregular kernel rows, are perhaps of this sort, and, if so, might be expected to remain indefinitely in their present percentages in any affected stock, unless some artificial means be employed to rid the stock of them.

Consider now the other extreme—abnormalities of such a nature that plants possessing them invariably perish without leaving progeny. Entire absence of chlorophyll is a recessive abnormality of this sort. No dominant abnormality of this class is known and in the nature of things could not be. If absence of chlorophyll had been a dominant character, it would have resulted in the destruction of the original mutant and, barring repeated production by mutation, would probably never have been seen. On the other hand a recessive abnormality, even though it cause the immediate death of every individual showing it, may exist indefinitely. Consider a case like the absence of chlorophyll. Suppose the original mutation arose in the heterozygous condition, which is most likely. The plant would have been green, but if self-pollinated 25 per cent of its progeny would have been white and 50 per cent would have thrown whites in the next generation, the other 25 per cent breeding true green. Since the whites die as seedlings, they would decrease in relative numbers in later generations, rapidly at first, much more slowly later. Thus the grandchildren of the original mutant (F_3 generation) would show only 11.11 per cent of whites, F_4 6.25 per cent, F_5 4 per cent, F_{10} 1 per cent, and so on (see fig. 1). One might suppose that at this rate such an abnormality would soon completely eliminate itself. And yet white seedlings crop our here and there year after year. The fact is that after the first few years this self-elimination is extremely slow. Thus if there is 1 per cent of white seedlings in the F_{10} generation, it will take ten years more to reduce the number to a quarter of 1 per cent, and after 100 years there would still be one-hundredth of 1 per cent of whites. After 200 years of such natural selection, 99 per cent of the stock should be pure green and most of the other 1 per cent, hybrid green and yet during the next 900 years the per cent of pure greens would increase only to 99.8 and the hybrid greens

would decrease only from 1 per cent to 0.2 per cent. Since any such mutation would from the start be in relatively very small numbers in any stock, the degree of its self-elimination in any one life time would be inappreciable.

If natural selection is so slow in completely eliminating an abnormality that causes the outright destruction of every individual pos-

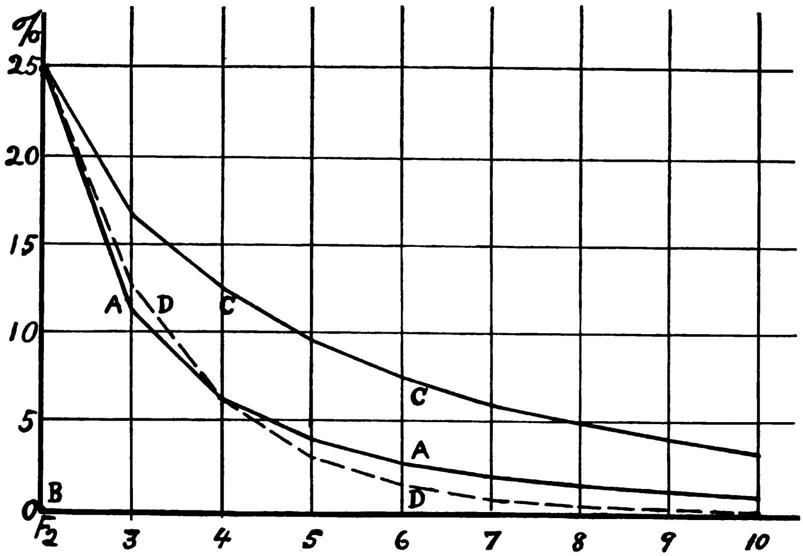


FIG. 1. PERCENTAGE OF ABNORMAL PLANTS IN GENERATIONS FROM F_2 TO F_{10} INCLUSIVE, WHERE FREE INTERCROSSING IS PERMITTED.

The F_1's are assumed to consist of 100 per cent heterozygous normal plants in case of "A" and "C" and of 50 per cent heterozygous abnormal and 50 per cent homozygous normal plants in case of "D."

A Recessive abnormality that causes the death of affected plants in the seedling stage. Per cent of abnormal plants in $F_n = \frac{100}{(n-1)^2+2(n-1)+1}$

B Dominant abnormality, otherwise like "A." It cannot exist beyond F_1.

C Recessive abnormality that results in the production of no seeds while not influencing pollen production.

D Dominant abnormality, otherwise like "C." Per cent of abnormal plants in $F_n = \frac{100}{2^n}$.

sessing it, what can we expect of it with abnormalities that merely reduce the production of seeds to a minimum while not interfering with the production of pollen as seems to be the case with yellow-green color of the plant? Or what of those cases in which the yield is lessened only very slightly? If a recessive abnormality resulted in the entire elimination of seed production, but did not interfere with the production of pollen, the per cent of abnormal plants would

be reduced from 25 in F_2 to about 4 in F_9 (see fig. 1) instead of F_5 as was the case above where the abnormality destroyed the whole plant. The final result would be about the same, however, only it would come somewhat more slowly. If yellow-green color in corn were a dominant abnormality with the same effect of practically eliminating seed production while not greatly lessening pollen production, the percentage of abnormal plants would fall somewhat more rapidly but there would still be about 1 per cent of them even after six or seven years (see fig. 1).

ERADICATION OF ABNORMALITIES

What is accomplished in the way of self-elimination by natural selection can be accomplished also artificially by ordinary methods of roguing and of mass selection and the final result will require the same length of time in one case as in the other. In case of any abnormality that can be detected early in the life of the plant, one can destroy every individual possessing it before pollen is shed, and thus accomplish the same result as natural selection would bring about with an abnormality that itself causes early destruction or complete sterilization of the abnormal plants. By this method one could completely eradicate a dominant abnormality in a single season and in five or six years could reduce the percentage of even a recessive abnormality to a point where it would no longer be of economic importance. Of course one could never be quite sure, however, of having completely eradicated a recessive abnormality by this method even though no abnormal plant were seen for several generations.

In case of abnormalities that can not be recognized until after the blossoming period, irregular kernel rows for instance, somewhat slower progress can be made by means of mass selection than where the abnormality can be detected earlier. The usual procedure in this case would be to avoid the use of seed from abnormal plants, to select, for instance, seed from straight rowed ears only. Obviously artificial selection of this sort could gain the end sought no faster than natural selection could eliminate yellow-green corn plants or any other abnormality that might prevent seed formation, without lessening the production of pollen. By seed selection alone, therefore, one might expect to reduce to an economically unimportant percentage such a dominant abnormality as fasciated ears in three or four years or such a recessive abnormality as irregular kernel rows in eight or nine years even though a large percentage of the stock were affected in the beginning.

While the results indicated above are perhaps all that are required in general corn breeding, there are doubtless some cases in which corn breeders would like to be able to eradicate absolutely some undesirable trait from an otherwise very desirable stock. Whether the character in question is commonly regarded as an abnormality or a "normal" character, that for some reason is not desired in the particular strain, is of no consequence, for characters that we call abnormal are probably not fundamentally different from those we are pleased to term normal. A certain variety of corn much grown in Nebraska must, according to the standard set up for it, have yellow grains and a red cob. There is no trouble about the grain color but, although no seed from white cobs is ever planted, a small percentage of white cobs are always produced. It would of course be perfectly easy to get rid of white cobs in this strain of corn, if it were worth the while, just as it would be to get rid of most any recessive character. Likewise red cobs or most any other dominant character could be completely eliminated from a strain of corn if we cared enough about it to take the necessary trouble.

There is only one way to accomplish such elimination in most cases and that is by pedigree cultures. This ordinarily necessitates self-pollination of individual plants. If the abnormality or other character to be gotten rid of is fully dominant, one can be sure that any selfed plant that lacks it will produce no individual showing it, and that it will not return in later generations except through out-crossing or by the much less probable means of a new mutation. In case the abnormality to be disposed of is a recessive one, some normal plants will transmit it to their offspring even though they do not show it themselves and even though they are self-pollinated. It is, therefore in this case, a matter of selecting normal progenies rather than normal plants. The only difference between getting rid of a dominant and of a recessive abnormality is then a matter of one year. It takes two years to eradicate a recessive character whereas only one is required for a dominant character.

But the corn breeder will at once recognize that this method of eradication of undesirable characters will, on account of its use of self-pollination, result in loss of vigor and he may prefer to keep the abnormality in a small percentage of his plants rather than to lose the normal vigor of his stock. His corn need not lose vigor permanently, of course, even though it be selfed one generation. If several normal plants or normal progenies can be obtained they will doubtless differ sufficiently in other characters to produce a vigorous stock again on being mixed and allowed to intercross freely.

A METHOD OF INBREEDING COTTON

W. W. Gilbert

Washington, D. C.

In connection with a line of breeding work looking toward the production of strains of wilt disease (Fusarium) resistant cotton of high productivity, sufficiently early to be adapted for use in boll-weevil territory and having other desirable qualities of boll and lint, a large number of crosses were made between several of the best large boll varieties used in weevil territory and the two wilt-resistant varieties, Dixie and Dillon, bred by the Bureau of Plant Industry of the U. S. Department of Agriculture. In the F_1 generation from these crosses, which were planted on land not infected with wilt, a few of the most promising plants were covered with cheesecloth frames to prevent crossing with undesirable plants or plants of other varieties growing in the vicinity. For the F_2 generation, however, enough selections were saved to plant about three acres and these were placed on wilt-infected land in order to eliminate as many as possible of the non-resistant individuals.

For the purpose of testing the effect of inbreeding in preserving and accentuating the quality of wilt-resistance when it appeared and to prevent the loss of this resistance by promiscuous crossing with the non-resistant individuals which would be present, a method of inbreeding was desired which would be less cumbersome than the old bag method and at the same time one that would not interfere with the normal development of the boll. Manifestly it would be impractical to cover several hundred plants with cheesecloth frames and, moreover, it was not possible under the circumstances, as we desired to make notes on the comparative earliness of the plants, and frames have a tendency to increase vegetative growth to an appreciable extent and delay maturity. Furthermore, the method of covering each flower with a paper bag is slow and tedious and the bags must be removed a few days after the bolls have set in order to permit normal development.

The method finally adopted consists in winding the flower-bud loosely with very fine flexible copper wire. The operation is performed when the flower has attained nearly full size but before it has begun to open at the tip. The wire used was No. 26 soft copper, which comes in 260-foot rolls costing about 20 cents. It can readily be cut up into desired lengths of 6 to 8 inches with a pair of small scissors.

The flower-bud is held very carefully in the left hand, the bracts of the involucre being turned back with the thumb and finger while one end of the wire is very lightly hooked through the corolla at the thickened portion near the base just enough to hold it, extreme care being taken not to go too deep and thus injure the interior flower parts. The end of the wire thus inserted is allowed to protrude about half an inch and is then turned over with the finger. This part of the operation must be done very carefully to avoid tearing the delicate corolla. With the finger still on the end of the wire

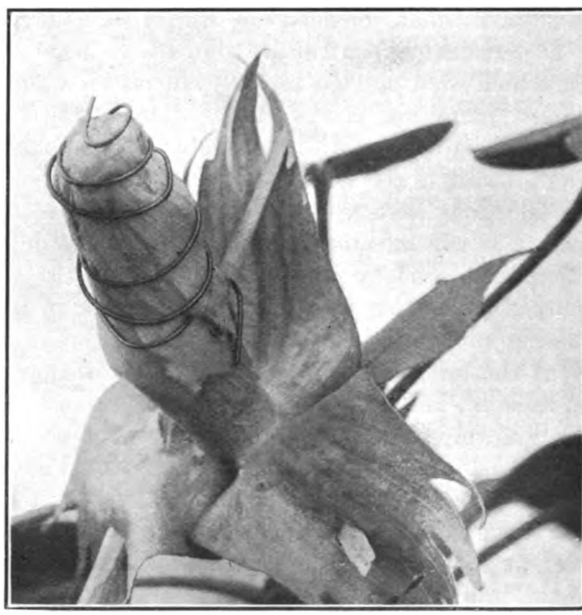


FIG. 1. COPPER WIRE METHOD OF INBREEDING COTTON FLOWERS.
Involucre turned back to show method of inserting wire at base of corolla.

the remainder is loosely wound spirally around the flower from base to tip, the spirals at the base being one-fourth to three-eighths of an inch apart and gradually becoming closer and smaller toward the tip until the spiral is closed just above the top of the bud (see fig. 1).

As the cotton flower increases in length very rapidly during the last twenty-four hours before it opens, the buds are not in the best condition to work with until 5 or 6 o'clock of the evening before the day on which they are to open. The work must therefore be

done after 5 p.m. and before 8 a.m. of the following day since by this time on the morning of a sunny day in July or August the tips of the flowers begin to open sufficiently to allow small insects to enter. Bees have been seen forcing flowers open before this time in the morning and entering to obtain honey.

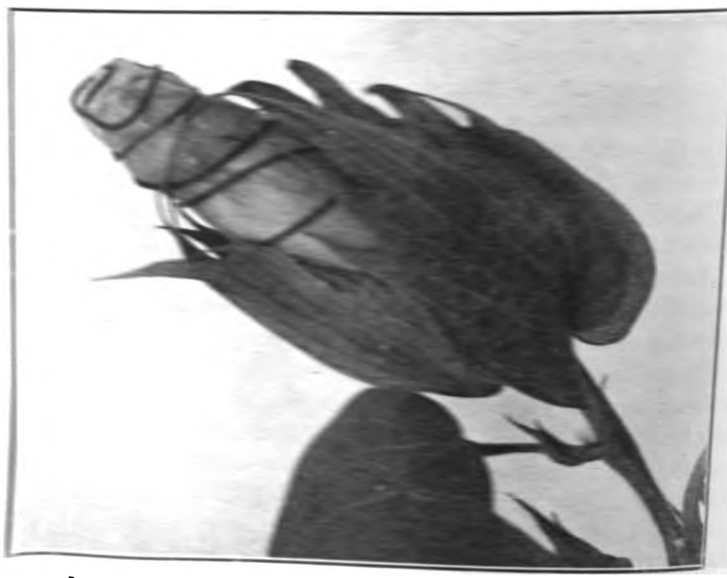
There is sufficient elasticity to the coiled pliable copper wire to permit the normal development of the flower parts but in no case has a wired flower been seen to open to allow an insect to enter. In fact, the slight growth that takes place after the flowers are wired forces the tip of the corolla into the end of the closed spiral and effectively seals it to the entrance of even the smallest insects.

Slight modifications of this method which were tried before the one above described was hit upon consisted in attaching the end of the wire either to the pedicel of the boll or to the involucre and completing the operation as above given in detail. The method finally chosen has the advantage over these, as over the bag method, that the wire being attached only to the corolla falls with it and leaves the boll to develop normally and it is not necessary to visit the flowers a second time to remove the bags. To mark the selfed bolls a very small white Dennison tag is merely looped over the pedicel of the flower. In case the boll fails to set or is shed later because of unfavorable weather conditions, or due to subsequent wilt infection of the plant, the tag falls with it and causes no confusion such as would result if the tag were fastened to the limb on which the boll is borne.

After one gets the knack of the operation it can be done very rapidly and with little or no injury to the flowers. First the field is gone over and the best plants are selected and tagged conspicuously with white or bright colored cloths so that they may be readily seen, and then from day to day the flowers are wired and tagged as they reach the right stage of development.

The conditions under which the work was done render the results in percentage of blooms finally harvested not at all comparable with results secured elsewhere where no disease factor is present. In the first place, it is not possible as early as July or the fore part of August, the time when inbreeding must be done, to determine just which plants will later succumb to the wilt disease, since many plants apparently in full vigor in late July are entirely dead by September. Furthermore neither the size of boll nor the length of lint can be determined at this time, as no bolls are matured. It is therefore necessary to select a large number of what then appear to be the most vigorous, productive, wilt-resistant and otherwise desirable

[illegible]



[illegible] ... Normal Posit[illegible]

[illegible] flowers on each [illegible] to be equal to those on the plants [illegible] there were [illegible] on the 105 plants finally [illegible] and [illegible] per cent, produced bolls. No record [illegible] of the total number of bolls which finally matured on wilted [illegible] plants.

[illegible] these figures Mr. F. L. Lewton of the Office [illegible] Breeding, Bureau of Plant Industry, advises me that in [illegible] breeding work at Yuma, Arizona, he secured about 50 per [illegible] from flowers merely covered with paper bags, the bags

being removed a few days after pollination had taken place. There the conditions are very favorable to pollination due to the occurrence of bright, sunny days and the almost entire absence of rain.

Under ordinary conditions in a humid climate the percentage of sets varies with the weather and with the time in the season when the work is done, from a possible 90 per cent in the early part of the blossoming period of the plant and in favorable weather to 10 per cent or less late in the summer and under unfavorable conditions.

Mr. E. C. Ewing of the Mississippi Agricultural Experiment Station has tested the method on a small scale with satisfactory results. He says, "I found it to be thoroughly effective and to require less time than the method of bagging."

VARIATION IN PURE LINES OF WHEAT

C. G. WILLIAMS

Wooster, Ohio

In 1907 the Ohio Station began some studies of variation in pure lines of wheat. By "pure line" is meant the progeny of a single head. Four characters are being studied. In this progress report two characters only will be considered—protein content and size of kernel.

Variation with respect to protein content.—This test has been carried on with two pure lines; one of Fultz wheat and the other of Poole. In determining the protein content of the heads used in this work, the kernels on one side of the rachis were used, the other half of the head being saved for planting. A preliminary test of 200 heads showed that the variation in the protein content of the two parts of the head when divided in this way was less than one-tenth of 1 per cent.

The initial planting was made in 1907. The head of Fultz wheat used analyzed 12.92 per cent protein. Of the progeny of this head, 100 good heads were analyzed. Their average protein content was 14.33 per cent. The 10 heads having the highest per cent of protein were chosen for the high protein strain Fultz. The head highest in protein analyzed 20.13 per cent and the 10 highest averaged 16.81 per cent (see table 1, first column). The 10 heads of the 100 having the lowest per cent of protein were chosen for the low protein strain Fultz. The head lowest in protein analyzed 10.38 per cent and the 10 lowest averaged 12.44 per cent. These 20 heads were planted in 1908, a head to a row, the high and low head-rows alternating.

The 80 heads intermediate in protein content were thrown into a "normal" strain to be carried along with the high and low strain as a check.

The original head of Poole wheat used analyzed 11.87 per cent protein. It was handled in the same manner as the Fultz head. The average protein content of the 100 heads chosen from the harvest of 1908 was 15.04 per cent. The protein content of the high, low and normal selections made from these 100 heads for planting is recorded in the first column of table 1. For the harvest of 1909, 10 good heads were harvested from each row, thus making 100 heads of each strain. The average protein content of these 100 heads is recorded in the second column of table 1. It will be noted that the protein content of the crop grown from the high protein Fultz seed exceeds that grown from the low protein strain by 0.58 per cent.

TABLE 1.—*Variation in pure lines of wheat with respect to protein content.*

Strain.	1908–1909.		1909–1910.		1910–1911.	
	Average per cent protein in					
	Seed used.	Crop harvested.	Seed used.	Crop harvested.	Seed used.	Crop harvested.
Fultz, High	16.81	12.53	15.26	14.35	19.17	16.82
Fultz, Low	12.44	11.95	9.95	14.56	11.64	16.61
Fultz, Normal	14.41	11.91	11.91	13.76	13.76	15.97
Poole, High	17.21	12.52	15.55	14.26	20.33	18.32
Poole, Low	12.08	12.63	10.24	14.25	11.22	18.01
Poole, Normal	15.13	13.51	13.51	14.42	14.42	17.85

In the case of the high and low Poole, this is reversed, the low protein strain showing 0.11 per cent higher protein content.

From the 100 heads analyzed of the high protein strains in both the Fultz and Poole pure lines, the 10 heads showing the highest per cent of protein were selected to continue the strain; and from the 100 low strain heads in each pure line the 10 heads showing the lowest per cent protein were used—the highest from the high, and the lowest from the low. The third column of table 1 gives the average per cent of protein in each set of 10 heads used to continue the strain. This work is continued in this manner from year to year and will be continued indefinitely.

Variation with respect to size of kernel.—Ten pure lines of Fultz wheat have been used in this study of variation. In the first planting two rows were planted from each head. One row with the ten largest

kernels, the other with the ten smallest. No shriveled kernels were used. The average weight per kernel of the seed used is recorded in table 2, first column.

In determining the comparative size of kernels in the crop harvested, 10 grams of kernels were counted. The results are recorded in the second column of this table.

TABLE 2.—*Variation in pure lines of wheat with respect to size of kernel.*

Plant number.	1908-1909.		1909-1910.		1910-1911.	
	Average weight per kernel of seed used.	Number of kernels in 10 grams of crop harvested.	Average weight per kernel of seed used.	Number of kernels in 10 grams of crop harvested.	Average weight per kernel of seed used.	Number of kernels in 10 grams of crop harvested.
	grams.		*grams.*		*grams.*	
8001-a	0.0342	356	0.0438	362	0.0412	264
8001-b	0.0229	351	0.0142	346	0.0175	292
8002-a	0.0340	398	0.0396	402	0.0375	290
8002-b	0.0254	438	0.0205	439	0.0212	289
8003-a	0.0362	338	0.0409	382	0.0375	284
8003-b	0.0223	340	0.0197	331	0.0162	289
8004-a	0.0474	394	0.0398	396	0.0337	304
8004-b	0.0321	384	0.0138	384	0.0137	284
8005-a	0.0396	312	0.0500	348	0.0487	247
8005-b	0.0239	279	0.0196	325	0.0150	263
8006-a	0.0350	352	0.0422	369	0.0375	289
8006-b	0.0232	360	0.0157	367	0.0175	312
8007-a	0.0355	393	0.0477	322	0.0450	253
8007-b	0.0240	306	0.0158	317	0.0137	279
8008-a	0.0296	480	0.0356	391	0.0387	301
8008-b	0.0159	513	0.0152	344	0.0125	334
8009-a	0.0393	342	0.0434	277	0.0437	281
8009-b	0.0264	337	0.0159	284	0.0187	272
8010-a	0.0354	353	0.0433	295	0.0450	279
8010-b	0.0212	380	0.0173	300	0.0137	307
Av. { a	....	372	....	354	....	279
Av. { b	....	369	....	344	....	292

Combined 3-year average—a 335 kernels in 10 grams.
Combined 3-year average—b 335 kernels in 10 grams.

a = Large-kerneled strain.
b = Small-kerneled strain.

Each strain was continued by selecting 100 kernels for planting; the largest kernels to be found in the lot grown from large-kerneled seed and the smallest plump kernels from the small-kerneled strain. It will be noted that the variation in the seed used is much greater the second and third years than in the first. This was made possible because of the greater amount of seed available in the different pure

lines. The first year there was of course only one head available for both strains.

Referring to the averages for each season at the bottom of the table, it will be noted that in the crop harvested the 10 large-kerneled strains averaged 372 kernels per 10 grams, while the 10 small-kerneled strains averaged 369 kernels per 10 grams, the latter strain thus producing slightly larger kernels. The averages for the second season give similar results, but in the third season it is reversed. The combined average of the three seasons' work shows identically the same number of kernels per 10 grams of grain of the crops grown from seed varying so widely in weight and size.

Taking into consideration the two characters studied, the data to date gives no encouragement for believing that there is any heritable variation in pure lines of wheat with respect to size of kernels or protein content.

OCCURRENCE OF NATURAL HYBRIDS IN WHEAT

L. H. SMITH

Urbana, Illinois.

Wheat is classed among the self-fertilized plants. It is of considerable importance to the wheat breeder to know whether it ever deviates from this habit, and if so, to what extent such behavior may be expected. The scarcity of information concerning this matter is pointed out in note by Dr. C. E. Saunders published in volume I of the *American Breeders' Association,* in which he calls attention to the discovery of a natural cross between Polish wheat and some unknown variety. In this connection Dr. Saunders states that, "so few cases of undoubted natural crosses are on record that it seemed to be worth while to publish the particulars in regard to this striking instance." It is the present purpose to add another bit of information along this line rising from some observations made in connection with our wheat breeding plots.

Before relating our own experience, however, I may state that upon looking up the subject I find a number of investigators have referred to this matter in a more or less definite way. Thus according to Fruwirth[a] such authorities as Rimpau, Hildebrand, Körnicke,

[a] Die Züchtung der landwirtschaftlichen Kulturpflanzen, vol. iv, p. 91.

Nowacki, and Delpino believe that while self-fertilization is the prevailing rule, cross-fertilization is a possibility and does sometimes occur, in some cases specific instances being mentioned. Garton, on the other hand admits of no such possibility.

Carleton recognizes this possibility and is inclined to attribute the origin of a number of our improved American wheats to this source.[b]

The most extensive, definite evidence, however, that I have come across is found in the work of the Howards in India. This work is published in the Memoirs of the Department of Agriculture in India, vol. 3, no. 6 by Howard, Howard and Kahn.

At the Experiment Station at Lyallpur, India, 226 cases of natural crosses were found among the pedigree cultures. A test of the progeny showing the hybrid nature in every instance is recorded. This remarkable result is explained by the authors as being due to the peculiar climatic conditions prevailing at that Station. They are of the opinion that a hot dry climate favors the occurrence of cross fertilization, so that while in a cool moist climate this behavior is extremely exceptional, in a hot and especially in a dry environment natural crossing may occur very frequently. It is stated in this connection that often where the soil is extremely dry the plants have been observed to wilt during the hottest part of the day, so as to open the glumes and expose the stigmas.

These observations, from the extent of the data included and the precision with which the tests were carried out, would certainly appear to be conclusive so far as the fact of the occurrence of natural crossing is concerned.

This very fact, however, serves to add interest to the matter for if such natural crossing is an element to be reckoned with in our breeding plots, it becomes highly important to know to what extent it may be expected under various circumstances.

In view of this, it is thought the following observations made in connection with our own wheat breeding cultures may be of interest.

In the summer of 1908, we were quite surprised to find in our Turkey Red breeding plot which had been planted with great care by the head-row system, a few plants here and there having smooth or awnless spikes. The rows of this plot had all been planted from typical Turkey Red bearded spikes, collected the previous summer in a field of that variety. Careful examination of their placement with reference to the rows satisfied us that these strangers were not

[b] Bul. 24, U. S. Dept. Agri., Div. Veg. Phys. and Path., p. 66.

accidental volunteer plants, but that they were actually the product of the seed which we had sown and that evidently we had to do with either a mutation or a hybrid. Subsequent results proved the latter to be the case. In the 96 rows of this plot, eight separate cases of this sort were found. The following year seed from each of these eight beardless plants was sown in separate rows alongside that from as many sister (or more strictly speaking half sister) bearded plants. The latter reproduced true to type in every case, but the beardless seed produced a crop which gave Mendelian segregation into bearded and non-bearded forms, the beardless character being the dominant.

Further propagation in pure lines has given in two subsequent generations the expected Mendelian behavior, the bearded segregates breeding true to this character while a proportion of the beardless split up.

Other characters segregating independently, such as color, length of spike, hairiness of glumes, have also been noticed in these strains.

From all of this evidence we are brought to the conclusion that the beardless plants found in our "pure" strains of Turkey Red were F_1 hybrids, resulting from the occasional accidental crossing of a flower in the mother plants.

These observations taken together with others on record lead us to conclude further that such natural crossing may occur more frequently than has been generally supposed, and that this may be a serious factor with which we have to deal in breeding operations and in the maintenance of the purity of varieties.

BREEDING ALFALFA AS A DRY LAND CROP

A. C. DILLMAN

Washington, D. C.

Drought resistance of alfalfa.—The importance of alfalfa as a forage crop has seemed to warrant all the efforts that have been made toward its improvement. The excellent feeding value of the forage, whether used as pasture or as hay, and for all classes of farm animals from "the great American hen" to the noble draft-horse, makes the crop of especial value whether grown under humid conditions or as a dry land crop.

The use of alfalfa, too, for soil improvement both on account of the nitrogen added to the soil and because of what we may term the sub-soiling effect of the deep roots, makes the crop valuable in

any system of crop rotation. It is rather exacting in its requirement for lime, but fortunately this element is found generally in the soils where dry farming is practiced.

The crop is of course especially adapted to use under irrigation because of its quick recovery after cutting and because of its long season of growth which allows three or more crops to be harvested each year. There are also certain favored localities in the dry land area in which ground water is found within a few feet of the surface where alfalfa can be grown to the same advantage as under irrigation. In these areas the crop can make use of a level of ground water which would be out of reach of shallower rooted crops. These are in brief some of the advantages of the crop in general. It may be well now to consider both its disadvantages and advantages as a dry land crop.

One of the faults of alfalfa as a dry land crop is its habit of continuous and long season growth, the very factor which makes it valuable under irrigation. Under dry land conditions this factor is a disadvantage for the reason that it is not possible to store a great amount of moisture in the soil of an alfalfa field to aid the crop in passing a dry period. The continuous growth causes it to use up the moisture as fast as it is available, and the result is, that in a season of limited rainfall, there is not enough moisture at any one time to produce a profitable crop. While, if it were possible to store in the soil the rainfall for a part of the season, the accumulated moisture would be sufficient to produce a normal yield. In the case of an annual forage plant, sorghum or millet for example, the growth is made in three months of the year, while the soil may be handled during the remainder of the year in such a manner as to conserve the rain that falls. In this respect the annual crop is no doubt better adapted to dry land conditions than is alfalfa.

In selecting a strain of alfalfa, or of any forage crop which will be at the same time productive and adapted to dry land conditions, we encounter the difficulty that by increasing the amount of vegetative growth, we increase the amount of transpiration and of water used. That is, large vegetative growth, which is the chief requirement of a forage crop, is opposed to economy in the use of water. If the required product were seed alone, as in the crops with which the grain breeder is concerned, then the problem would be easier. I have observed numerous individual plants and several progeny rows of alfalfa that were excellent in seed production but were seriously lacking in forage production. Such a type of plant, with few stems and leaves, may no doubt be economical in its use of water,

and may be efficient in seed production, but is worthless from the forage standpoint. It is necessary I believe to keep in mind that forage production is the first requisite, even though other types may show greater water economy.

In regard to the actual drought resistance of alfalfa, it is necessary to distinguish between the behavior of the green portion of the plant and the plant as a whole. It is a matter of common observation that when the fully developed leaves and stems wilt badly, due to drought, their growth is permanently checked and they will not revive so as to continue growth with return of favorable conditions, but instead the plant will start out new shoots from the crown. In this respect alfalfa is very different from sorghum which is able to cease growth during a dry period of considerable duration and to revive with normal growth on the return of favorable conditions. This lack of drought endurance of the growing stems of alfalfa may appear a fault, but in reality is of great advantage to the plant in stopping transpiration before the soil moisture is entirely exhausted. In this way vitality is retained in the crown and roots of the plant with which to develop new stems when favorable conditions recur. The dormant condition which alfalfa enters during a period of drought is not unlike the dormant condition during winter; the leafy stems wilt, but the drought endurance, like the cold endurance, is found in the roots and crown of the plant.

The remarkable drought endurance of the plant was proved during the past season at the Bellefourche, South Dakota, Experiment Station where the season was extremely dry. There was not enough rain at any time before August to germinate the grains seeded in March or start the growth of alfalfa and of the native grasses. The alfalfa remained dormant during this period which included the hot summer months, but started growth when rain fell in the latter part of August. Only a small percentage of the plants were killed outright by the drought. Alfalfa proved one of the most drought resistant of the cultivated perennial crops and stood the drought nearly as well as the native grasses—buffalo grass and western wheat grass.

In breeding alfalfa as a dry land crop it is necessary to keep in mind in what respect drought resistance can be obtained. It was formerly believed that plants differed widely in their ability to draw upon the soil moisture. It was thought that by virtue of a stronger "root pull" some plants could continue to absorb moisture and grow in a soil where other plants would wilt and die from lack of moisture.

Recent investigations[a] have shown that plants differ but slightly in this respect.

In selecting plants for drought resistance then, we must look for some other cause to account for the superior growth of one plant over that of its neighbors. This superior growth may be due either to a greater root development or to a greater economy in the use of water, that is, a less volume of water used per unit of dry matter produced. All investigators have found a vast difference in the water requirement of different cultivated crops and this suggests the probability that there are differences in the water requirement of varieties and strains of each crop. This is indicated, too, by the experience of investigators of grain crops who have found some varieties yielding much better under conditions of drought than others. The Nebraska Station[b] has found that a narrow leaf strain of corn yielded considerably more than a broad leaf strain both selected from the same variety, Hogue's yellow dent. And so in breeding alfalfa as a dry land crop we should seek plants having a low "water requirement." In field work a comparative test of the water requirement can be obtained by the method of testing selections in progeny rows, provided the soil conditions are uniform. The weight of dry matter produced under conditions of limited moisture supply becomes a measure of the efficiency of the plant in its use of water.

Breeding methods employed.—The breeding methods used fn this work are not new in principle, but may be worth describing briefly.

At the beginning of the work all strains of alfalfa which could be obtained from various sources in this country and Europe were tested for hardiness and forage production. This test eliminated a large number of strains, chiefly on account of lack of hardiness, and proved the decided superiority of the four or five strains which were retained as foundation stocks.

These hardiest strains were then planted in selection rows where the plants were allowed to develop normally without crowding, so that the individual characters of each plant could be studied. It is convenient in keeping notes to have the plants at definite distances apart, as one would check-row corn in hills, so that the plants are in line in both directions. In this way one can designate each plant by number from the position it occupies in the row, and thus avoid the use of stakes which are easily lost or destroyed in cultivation.

[a] Briggs, Lyman J. and Shantz, H. L., The Wilting Coefficient of Different Plants and Its Indirect Determination. Bulletin 230, Bur. Pl. Ind., U. S. Dept. Agri.

[b] See Twenty-fourth Annual Report, Neb. Exp. Sta., p. ix.

If a plant is missing in the row the order of numbering is not changed, each plant in the row being permanently designated by the position it actually occupies.

From the selection rows numerous individual plants which combined the best forage type with a tendency toward good seed production were selected, and the following year seed from these was planted in progeny rows (fig. 1) in the same manner as the selection rows were planted. A detailed description is kept of each individual

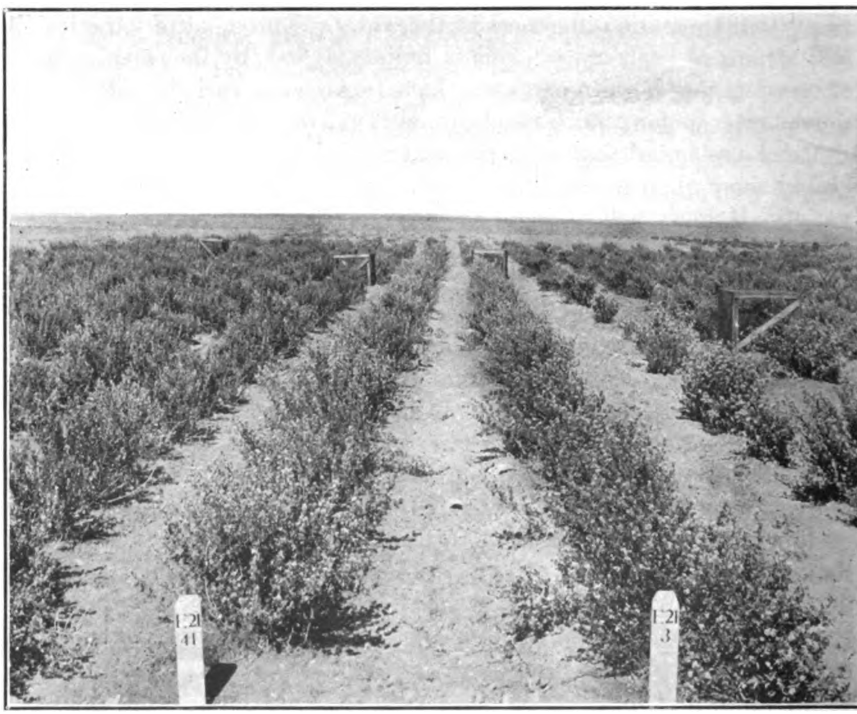


FIG. 1. PROGENY ROWS OF ALFALFA.

From seed of individual plants which represent the fourth generation of selection from Grimm alfalfa. Bellefourche Experiment Farm, June 21, 1911.

selected as a mother plant, and in most cases a photograph is taken of the mature plant (fig. 2). We use a score card with appropriate headings for taking notes, and complete the description by writing out in full such data as are not covered by the headings. These cards are bound into a note-book for use in the field, but are perforated at the binding so as to be torn out and filed in a convenient manner for reference. The notes include: (1) The type of plant—whether

erect, spreading, or decumbent; (2) The character of the stems—whether coarse and woody, or fine and succulent; (3) The amount and character of branching including the number and length of internodes; (4) The relative leafiness together with the shape and size of the leaves; (5) The flower color; and (6) The seed production

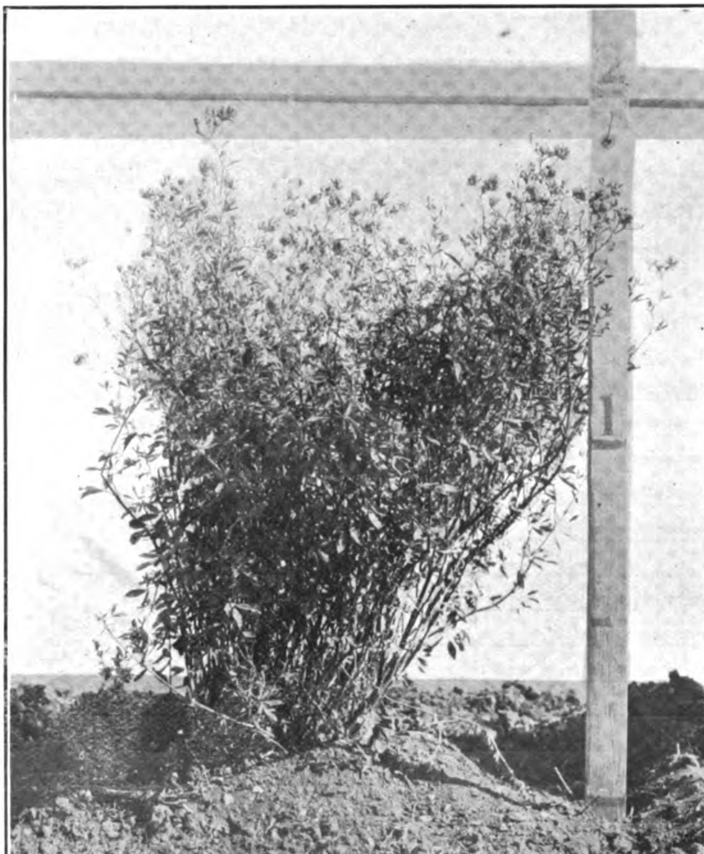


FIG. 2. A DESIRABLE TYPE OF ALFALFA PLANT.
Erect, with numerous fine stems, leaves abundant, and seed production good.

as estimated from the number of pods and the number of seeds per pod. After harvest the yield of the plant is entered—including total dry weight, weight of seed, and percentage of seed to total weight. This last record, percentage of seed to total weight, is a convenient index of the relative seed producing ability of the plant.

The plants which are tentatively selected at the period of blossoming are carefully compared at the time the seed is ripe, and only those which show combined excellence in forage type and seed production are finally chosen. These are cut separately and each is placed in a cloth bag to dry.

Crop, *A. & D. No.*

Date, *, 191* *Station,*

LOCATION: Plot Row Plant No.

DATE: Planted Growth starts

First bloom Full bloom

Ripe Harvested

Type of plant

Height Stools, number of

Internodes, number of Length

Leaves, number of Length Width

Pods, number of Seeds per pod

Drought resistance

Growth after harvest, vigor Height

YIELD:

Weight of plant Seed Straw

Percentage of seed

Number of seeds per gram weight

FIG. 3. SCORE CARD USED FOR INDIVIDUAL PLANT SELECTIONS OF ALFALFA.

In order to compare the value of the progeny rows careful notes are taken on each plant in the row (see fig. 4) at the beginning of the blossoming period, since the forage type of the plant is best judged at this time. After these notes are taken all the inferior plants, as well as all that are divergent from the type of the row, are removed in order to prevent cross pollination from these undesirable plants. Later in the season, when the seed is ripe, the best

individual plants are selected and handled as described, while the remaining plants in each row are harvested in bulk, dried in shocks, weighed and threshed. Since a record is kept of the number of plants harvested, an accurate estimate can be made of the producing power of each progeny row.

The yields of several progeny rows grown at the Bellefourche Station, S. D., in 1909 are shown in table 1.

TABLE 1.—*Showing yields of progeny rows of alfalfa grown at Bellefourche, S. D., in 1909. Variety E is Grimm alfalfa, Variety F is Turkestan.*

Variety and progeny number.	Average dry weight per plant.	Average seed yield per plant.	Percentage of seed to total weight.
	grams.	*grams.*	
E1	171	27	16
E2	171	18	10.5
E4	189	33	17.5
E5	144	23	16
E6	192	32	16.5
E7	150	25	16.5
E9	150	22	14.5
E10	138	22	16
E12	150	21	14
E13	138	19	14
E15	180	27	15
E17	138	20	14.5
E18	165	28	17
E19	180	33	18.5
Average of strain *E*.......	161	25	15.5
F1	144	18	12.5
F2	150	20	13.5
F3	150	19	12.5
F5	135	14	10.5
F6	132	15	11.5
F7	134	22	16.5
F8	192	28	14.5
F9	144	17	12
F11	144	20	14
F12	180	30	16.5
Average of strain *F*......	150	20	13.4

The average of all progeny rows in strain *E*, representing 600 plants, was 161 grams dry weight and 25 grams of seed per plant.

In strain *F*, 354 plants averaged 150 grams dry weight, and 20 grams of seed.

It will be seen that six progeny rows in strain *E* produced forage and seed above this average of the entire strain. These were E1,

E4, E6, E15, E18 and E19. And in strain *F* two progeny rows (F8 and F12) yielded above the average of the strain.

Under the conditions where these progenies were grown, where lack of moisture was the chief limiting factor in crop production, these results should in a measure indicate the relative efficiency in

Alfalfa—Individual Notes. *A. & D. No.*

Date, , *191* *Station,*

Plant number	1	2	3	4	5	6	7	8	9	0
STAND: Sept. , 191										
May , 191										
DATE: Growth starts										
First bloom										
Ripe										
Drought resistance										
Type of plant										
Branching										
Leafiness										
Color of blossom										
Seed production										
Plants discarded										
Plants selected										

FIG. 4. SCORE CARD FOR ALL THE PLANTS IN A PROGENY ROW.
By inserting the tens figure before the 1, the series becomes 11 to 20, or 21 to 30, etc., as desired.

the use of water of the progenies tested. Seed from the best progeny rows has been planted in a duplicate series of one-tenth acre plots in comparison with the original stocks of Grimm and Turkestan alfalfa and will be tested further in order to determine what progress has been made.

There is at least one fault, however, in the ordinary row method of testing progenies, and that is, there is no check made on the root development of the different selections. So that a vigorous, early developing selection may extend its roots far into the area that belongs to the slower growing progenies at each side, and thus draw upon a much greater volume of soil moisture than its neighbors (fig. 5). To avoid this condition we plan in future work to plant

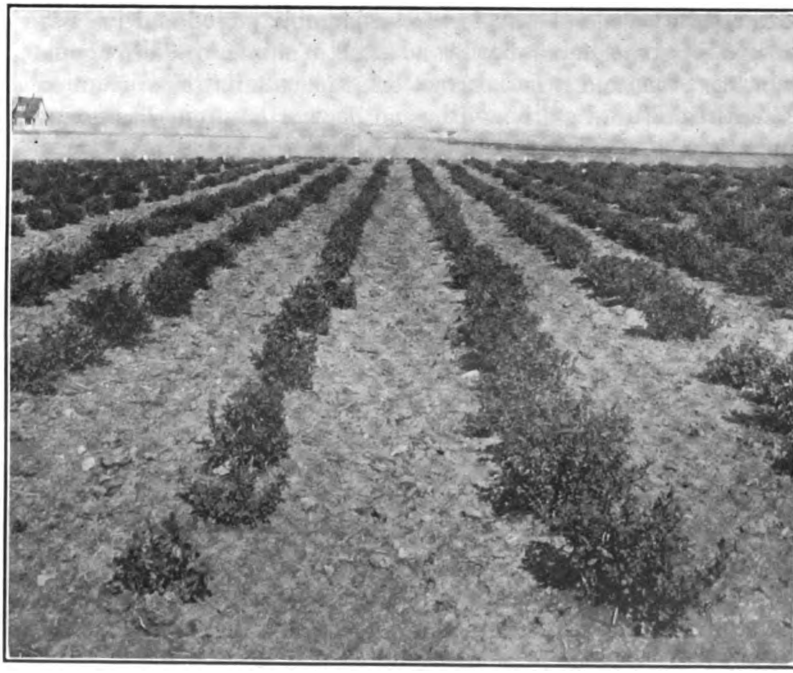


FIG. 5. THE ROW AT RIGHT OF CENTER HAS AN ADVANTAGE OVER THE ROW AT LEFT IN SECURING SOIL MOISTURE BECAUSE OF ITS GREATER VIGOR.

By planting three adjacent rows of each selection, the middle row can be grown in competition with plants of its own kind.

each progeny in three rows side by side, and then consider only the middle row in our estimates of yield, uniformity, etc. In this way each middle row is put in competition with plants of its own kind, and any superiority that one progeny may show can be attributed to real efficiency in that progeny, rather than to any advantage in the circumstances of growth.

INFLUENCE OF VARIEGATION IN ALFALFA UPON HARDINESS

L. R. Waldron

Dickinson, North Dakota

Great variation exists in various races or place-strains of alfalfa, obtained from different geographical sources, in regard to their hardiness when brought to northern regions. This fact has been recognized in a general way for a considerable period and has been discussed in some detail by Brand and Waldron.[a] The popular notion has been, and it is a correct one, that alfalfa taken from one northern region and cultivated in another northern one has greater chances for success than an alfalfa so cultivated taken from a southern region. The idea has been popular, but its correctness has not been proven, that any alfalfa grown in southern regions would, if brought northward, gradually take on hardiness from year to year so that in the course of time it becomes "acclimated" to winters of severe cold.

In the bulletin previously cited, page 65, it was suggested that any race of alfalfa is made up of various lines which have different degrees of hardiness, and that a race introduced from one region to another, the latter having the colder winters, would undergo changes, the tender lines becoming eliminated, the more hardy ones persisting. If such lines were kept selfed for a number of generations, different biotypes would be produced within the race, some having greater hardiness than others.

Westgate[b] suggests that hardiness of certain races is due in greatest measure to the fact that they show previous crossing with *Medicago falcata.* This crossing is indicated by certain peculiarities of flower color easily recognized.[c] It is apparent that no scientific study of the problem is possible within the pure *M. sativa* until we secure, by breeding, various biotypes, which evidently have a potential existence; and then it must be determined if certain biotypes are hardier than others and, if the hardy ones exist, whether such hardiness be retained.

With the variegated alfalfas it will be necessary, again, to breed to obtain the biotypes, to determine whether variegation is uniformly

[a] Brand, Charles J. and Waldron, L. R., Cold Resistance of Alfalfa. Bulletin No. 185, Bur. Pl. Ind., 1910.

[b] Westgate, J. W., Variegated Alfalfa. Bulletin No. 169, Bur. Pl. Ind.

[c] Waldron, L. R., Variegation in Alfalfa. Science, N. S. xxxiii, 1911, p. 310.

distributed among the biotypes, whether some biotypes are hardier than others, and, if such hardiness is retained, whether the variegation in the biotypes is associated with hardiness. By various crossings, one would be able to determine how hardiness acts from one generation to another.

Brand[d] has stated that the crossings with *M. falcata* in producing diversity have given great opportunities for the environment to develop strains of greater hardiness. His idea evidently is that the presence of the diverse characters allows more rapid and more extensive amelioration in regard to hardiness than would otherwise be possible. This amelioration might easily take place if we consider that hardiness is a complex character conditioned upon different physical features present in different biotypes and subject to the laws of alternative inheritance. The critical studies along the lines suggested must be left for the future.

The writer has had a chance to work with a number of place-strains[e] or races of variegated alfalfas in a district where hardiness in the plant is essential to its successful culture. An effort was made to learn whether the variegation present could be correlated in any way with hardiness. The results are largely negative. This may be because such negative results represent the facts but the methods employed, while good in themselves, were not applied to material that had been biologically analyzed. It will be plainly seen that had a biological analysis been made of the data, the results would have held more interest and value. With more refined methods the results might still have been negative but upon such results, one could place more reliance.

Table 1 presents us with various data, among them being the source of the alfalfas, the number of plants involved, the per cent dead, the per cent variegated, and the means of the plants in the spring of 1911. In securing the last-named data, the dead plants were given a rating of "0" and the live plants were rated from "1" to "10" according to their size and vigor. It is evident then that the complements of the "per cent dead" are comparable to the "means of 1911." Each race comprised generally 40 to 50 plants. The means, etc., were determined for each race and then each race used as a unit. The probable errors were calculated for the 1911 means

[d] Brand, C. J., Grimm Alfalfa and Its Utilization in the Northwest. Bulletin No. 209, Bur. Pl. Ind., p. 10.

[e] The place-strains in question were grown at the Dickinson, N. D., Sub-station. The seed of these were obtained largely through the energy of Mr. Charles J. Brand and the planting of them was due to his initiative.

TABLE 1.—*Gives various data with reference to the influence of variegation upon hardiness in alfalfa.*

S. P. I. number.	Name and source.	Number of plants.	Per cent dead.	Mean of 1911.	Number of variegated plants.	Per cent variegated.
23481	Coml. Sand Lucern, Hamburg, Germany	42	26.2	4.88	8	20.0
24602	Provence alfalfa, Germany	42	71.4	1.00	17	40.5
24603	Coml. Sand Lucern, Erfurt, Germany	42	50.0	3.29	15	35.8
24635	Old German Franconian, Baden, Germany	41	9.8	5.96	14	34.2
24667	Old German Franconian, Bavaria, Germany	46	10.9	6.26	25	54.4
24717	Bohemian alfalfa, Austria	45	46.7	2.71	8	18.3
24718	Moravian alfalfa, Bohemia	44	25.0	4.05	10	23.3
24719	Hungarian alfalfa, Austria	44	18.3	4.86	8	18.6
24720	Provence alfalfa, Germany	40	42.5	3.45	5	12.8
24721	Provence alfalfa, France	35	22.8	4.34	11	31.5
24722	Provence alfalfa, France	45	53.4	1.96	10	22.2
24723	Russian alfalfa, south Russia	46	4.4	7.78	7	15.2
24724	Russian alfalfa, north Russia	41	41.5	2.52	4	9.7
24725	Spanish alfalfa	34	14.7	4.50	2	6.0
24727	German alfalfa, Baden	44	18.0	3.64	12	27.3
24728	German alfalfa, Baden	44	11.3	4.86	10	22.7
24729	Hungarian alfalfa, Austria	44	25.0	3.57	6	12.7
24730	Russian alfalfa, south Russia	46	2.0	6.09	8	17.4
24731	Russian alfalfa, south Russia	45	0.0	6.45	5	11.1
24732	Russian alfalfa north Russia	46	19.5	3.20	6	13.0
24733	Old German Franconian, Baden, Germany	43	14.0	2.67	21	49.0
24734	Provence alfalfa, Germany	42	47.6	1.50	4	9.5
24735	Italian alfalfa	38	31.6	1.45	10	26.2
24736	Spanish alfalfa	37	70.4	0.35	0	0.0
24737	Coml. Sand Lucern, Bohemia	42	47.6	0.95	4	9.7
24740	Italian alfalfa, north Italy	42	28.6	2.14	14	33.4
24741	Com. Sand Lucern, Bohemia	44	6.8	5.57	12	27.3
24767	Old German Franconian, Baden	42	21.4	2.81	13	31.0
24923	Old German Franconian, Württemberg	43	21.0	2.21	16	38.0
24928	Provence alfalfa, Germany	38	71.0	0.50	6	15.3
25022	Old German Franconian, Baden	43	9.3	3.23	14	32.6
25091	Coml. Sand Lucern, Strasburg	42	26.2	2.45	12	29.2
25115	Coml. Sand Lucern, Bromberg, Prussia	37	56.8	0.89	11	29.8
25167	German alfalfa Thuringia	41	46.8	1.90	8	19.5
25168	Coml. Sand Lucern, Bohemia.	40	5.0	6.20	0	0
25175	Old German Franconian, Bavaria, Germany	39	10.2	5.59	24	56.0
25176	Coml. Sand. Lucern, Bohemia	43	46.5	1.81	9	21.0
25181	Pfalzer Lucern, Bavarian Palatinate	14	28.6	1.57	2	14.3
25182	Eifeler Lucern, Rhenish Prussia	13	7.7	5.23	7	54.0
25183	Old German Franconian, Baden	13	69.2	0.92	4	30.4
25184	Provence alfalfa, Germany	15	53.3	1.00	7	46.6
25193	Old German Franconian, Baden	40	25.0	2.88	10	23.0
25194	Old German Franconian, Bavaria	39	71.9	0.72	13	40.5
25257	Pfalzer Lucern, Baden	35	65.6	0.80	11	39.4
25267	German alfalfa, Prussia	36	39.0	3.89	18	51.5
25268	Coml. Sand Lucern, Bohemia	38	52.6	2.34	8	21.4
23394	Coml. Sand Lucern, France	36	55.6	1.08	9	26.3
25119	Vienna, Austria	39	33.4	2.87	2	5.2
25178	Coml. Sand Lucern, Bohemia	40	20.0	4.10	25	64.2

TABLE 1.—Continued.

S. P. I. number.	Name and source.	Number of plants.	Per cent dead.	Mean of 1911.	Number of variegated plants.	Per cent variegated.
25179	Hungarian alfalfa, Austria	40	37.5	2.47	3	7.5
25180	Moravian alfalfa, Bohemia	41	46.4	1.61	4	10.3
25111	Coml. Sand Lucern, Switzerland	22	31.8	2.32	5	22.3
25112	Coml. Sand Lucern, Switzerland	24	16.7	5.38	6	25.0
24858	Italian alfalfa, Florence	41	39.2	2.39	6	15.0
25187	Italian alfalfa, Pisa	38	60.6	1.45	6	16.6
25186	Algerian alfalfa, Setif, Algeria	20	45.0	2.65	2	10.5
34270	Bucharest, Roumania	23	39.1	1.43	4	17.4
25270	Roumanian alfalfa, northern	37	81.1	0.78	7	19.4
25109	Austrian alfalfa, Vienna	39	7.7	4.15	0	5.4
25185	Hungarian alfalfa, Austria	13	46.1	1.31	1	7.7
25110	Coml. Sand Lucern, Switzerland	22	22.7			72.7

and were found to be a little less than one-tenth of the means. The standard deviations of the 1911 means were calculated but their presentation would not have aided much in the understanding of the work.

In order to apprehend the data presented in table 1, it will be well to analyze them somewhat. We may correlate the per cent of the plants variegated with the per cent of the plants dead, the result of each strain being considered as a unit. The data so arranged are presented in table 2. From this we learn that the coefficient of

TABLE 2.—*Correlation in alfalfa.*

Means of the per cent variegated subject, means of per cent dead relative. Coefficient of correlation -0.09 ± 0.09.

Per cent variegated.	Per cent dead: 0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	Totals.
0–10	2	1		2	4			1		10
11–20	3	2	2	2	5		1	1	1	17
21–30	1	3	4	2	1	4				15
31–40	2		4			1	2			9
41–50		1				1		2		4
51–60	2	1		1						4
61–70			1							1
71–80			1							1
Totals	10	8	12	7	10	6	3	4	1	61

TABLE 3.—*Correlation in alfalfa.*

Means of the per cent variegated subject, 1911 means relative.
Coefficient of correlation + 0.09 ± 0.09.

Per cent variegated.	1911 Means. 0 to 1	1.1 to 2	2.2 to 3	3.1 to 4	4.1 to 5	5.1 to 6	6.1 to 7	7.1 to 8	Totals.
0–10	2	2	2	....	3	....	1	....	10
11–20	2	5	3	3	1	....	2	1	17
21–30	1	4	4	1	3	2	....	....	15
31–40	2	....	3	2	1	1	....	....	9
41–50	1	2	1	....	....	....	....	....	4
51–60	....	....	....	1	....	2	1	....	4
61–70	....	....	1	....	....	....	....	....	1
71–80	....	....	....	1	....	....	....	....	1
Totals....	8	13	14	8	8	5	4	1	61

correlation is $- 0.09 \pm 0.09$. It is evident that the correlation is essentially zero. Had the coefficient of correlation been considerably greater than the probable error, our results then would have shown that an increased variegation in any strain was associated with increased hardiness. Though even then, without more careful biological analysis, one would not be safe in asserting that the variegation was the cause of the increased hardiness.

Table 3 is presented which is somewhat similar to table 2. In this case the per cent of the plants variegated is correlated with

TABLE 4.—*Alfalfa data grouped in reference to geographical origin.*

Number of races.	Source-name.	Per cent dead.	Average deviation.	1911 mean.	Per cent variegated.
2	Turkestan	8.4	3.6	5.49	0
2	Spanish	42.6	27.9	2.48	3
2	Austrian	20.6	12.9	3.51	2.6
1	Algerian	45.6	....	2.65	10.5
3	Hungarian	26.9	6.9	3.63	12.9
5	Russian	13.5	13.6	5.21	13.3
2	Moravian	35.7	10.7	2.83	16.8
1	Bohemian	46.7	....	2.71	18.3
1	Roumanian	81.1	....	0.78	19.4
4	Italian	39.9	7.9	1.86	22.8
7	Provence	51.7	12.1	2.29	25.5
2	Palatine (Pfalzer)	47.1	18.5	1.19	26.8
14	Commerical Sand Lucern	33.2	15.7	3.15	28.9
4	German	28.8	14.1	3.57	30.2
10	Old German Franconian	26.3	17.7	3.33	38.9
1	Eifel	7.7	....	5.23	54.0

the spring condition of the plants, the 1911 means. In this case we find the coefficient of correlation to be 0.09 ± 0.09. As the 1911 means are the complements of the per cent dead, then a negative correlation in one case is the same as a positive correlation in the other. As the probable error equals the coefficient, the coefficient of correlation is again essentially zero. From these methods of handling the data, it is evident that we can not be sure that variegation is correlated with increased hardiness.

It is possible to arrange the various strains of alfalfa somewhat according to their geographical origin. This is done in table 4.

Table 4 shows some of the strains, such as Provence, having considerable variegation but which nevertheless are tender. The six place-strain groups occurring last in the table, taken in their order, show a progressive increase in variegation and a corresponding decrease of the per cent dead. The same criticism may be applied to this method of handling the data as was previously given. It may be well to state here that the data were manipulated in other ways, but no better results were obtained than those given.

In conclusion it may be said that the non-success of the statistical method, when applied to the work in hand, is not due to the faultiness of the method at all, but rather to the unorganized condition in which we find our data. The alfalfa strains should first be purified by a few generations of breeding.

BREEDING CERTAIN FIELD-CROP PLANTS IN THE COLD NORTHWEST

L. R. WALDRON

Dickinson, North Dakota

The areal extension of the four cold-enduring crops, fall wheat, fall rye, alfalfa, and red clover, would mean much to the wealth increase of the cold Northwest. While the success of some or all of them is undoubted for certain localities, their challenge for continued extension and further improvement summons the best efforts of the disciplined plant breeder.

ACCLIMATIZATION OF FALL WHEAT

The subject of acclimatization is often not given critical consideration. The term may cover several ideas from a semi-technical stand-

point. We should distinguish, for instance, between the acclimatization of annual and of non-annual plants. Hansen[a] has pointed out the difference in shortening the life history of an annual plant, such as the corn plant, so that it may ripen in a shorter (and colder) northern season and in actually putting hardiness into such a perennial as the alfalfa plant.

It is a common belief among laymen and among many scientists as well that fall wheat has gradually increased in hardiness during the last thirty or more years so that it can now be grown with success in regions where formerly it would have failed.[b] The evidence for this belief is popular rather than scientific.

It is a common statement among pioneer farmers that when the country was first settled certain crops, such as timothy, would not succeed. Regarding this point, it is almost certain in many cases that the first attempts in cultivating the new crop were made in a sporadic and in a half-hearted manner. Ignorance of proper agronomic methods was undoubtedly a determining factor in the success of or non-success of the new crop, in many instances. Had the farmers possessed at the beginning that knowledge of the crop and of local conditions gained by many years of later experience, a much greater degree of success would have been attained at the outset. Without considering the matter closely, it is often assumed that there has been some change in the plant, or in the climate, allowing the crop to withstand conditions impossible at the beginning. It would seem that here the farmer rather than the crop has become acclimatized.

It should not be forgotten that the importation of fall wheats from other countries, where they have been grown for long periods of time, might exert considerable influence in extending the range of fall wheat to severer sections where it has not been possible to succeed with the domestic sorts.

ACTIVE ADAPTATIONS

Another point may be considered which might influence the plant in such a manner that it would be better able to endure cold without, however, influencing the heredity of the plant. The point is largely

[a] Hansen, N. E., Hardy Alfalfa, *Dakota Farmer*, February 15, 1911.

[b] Lyon, T. L., Nebraska Bulletin No. 72, makes a conservative statement of the case when he says: "Such adaptation has actually been going on for a number of years, which may in some measure account for the fact that winter wheat is now being grown in portions of Nebraska where twenty years ago it was considered an impossible crop."

hypothetical and may have no existence in fact. For a better understanding of this, the alfalfa plant may be considered. Many plants have active adaptations which allow a successful life impossible without them. I might cite the oft-mentioned cypress of the southern coasts. The bald cypress develops aërating "knees," which are necessary for the existence of the plant when it grows in water. They are not present when the plant is wholly terrestrial. The adaptation is not transmitted, is still active, and so has not become passive.[c] Other instances are certain alpine plants which take on a normal appearance when taken to lower altitudes and grown there.

It is commonly stated that alfalfa is most liable to winter-kill during the first winter, other things being equal. My observations tend to support this belief. There may be a variety of causes for this. It is not inconceivable that one of the causes may be an active adaptation tending to protect the plant against cold. We are very much in the dark as to the exact origin of the aërating knees of the cypress or of the adaptations of the alpine plants. The fact of their existence and the nature of the adaptations are very obvious. Similar adaptations may exist in the alfalfa plant, though apparently hidden. Up to the present time, perhaps, their existence has not been thought of.[d]

As with alfalfa, so conceivably in a measure with fall wheat. It is possible to think that with a gradually oncoming winter certain active adaptations might make themselves known within the wheat plant, perhaps protoplasmic in character, allowing the plant to endure greater extremes of cold than would otherwise be possible. Such adaptations would be of a different nature from those which tend to lessen the turgescence of the plant. But such adaptations could not be expected every year. Their presence would be dependent upon the weather.

THEORY OF PURE LINES

In considering whether changes have actually been brought about in the fall wheat plant, enabling it to be grown farther and farther north, during the last generation or so, one must not neglect the theory of pure lines.

The fact that a general variety or "Landsorten," of grain, like

[c] Jost, Plant Phys., Oxford, p. 390, 1907.

[d] If the somewhat decumbent nature of the Grimm alfalfa, and some others, is an adaptation to endure winter cold, it has become passive and therefore heritable. For other possible adaptations looking towards cold endurance see Bulletin 185, Bur. Pl. Ind., p. 68. This is by Charles J. Brand and the writer.

the Turkey Red fall wheat, is composed of a number of strains breeding true, is well attested. It would be almost a truism to state that the different strains had in some measure different degrees of hardiness. It is quite evident that such a variety when moved to a region with severer winters loses the representatives of the more tender strains and in consequence the representatives of the hardier strains within the variety become predominant.[e] It is manifest that on this basis there has been no absolute increase of hardiness within the variety. The resulting increased cold endurance has been brought about by purely mechanical means. The germ plasm remains quite unmodified.

There appears to be no reasonable doubt but what the factor of pure lines plays a part in the problem of hardiness, but to what extent we are in almost entire ignorance. The range of variation among the different strains or pure lines may amount to little or it may amount to much. As the tender strains die and leave no progeny the problem is more than ordinarily difficult of analysis.

With the recognition of the presence of many strains within a variety, all approaching in a general way very closely to the phenotype, there enters also a recognition of the fact that such strains must be rather closely related, and the problem of common origin remains for solution. We will start, let us say, with a single head of Turkey Red wheat and increase it.

The increase is to be grown by itself, away from other varieties, to prevent the rare intercrossing that might take place, and also to avoid mechanical mixing. The problem is, to determine how rapidly the original pure strain, increased from the single head, develops into a variety containing many strains approaching in some measure the heterogeneity of the Turkey Red, with which we are familiar.

It is the old, old problem expressed concretely; but a study of wheat, it would seem, offers a splendid field for some clue to the answer of the general problem. If mutations occur, and it is probable that they do, then they must often be slight, for the differences that separate the various strains or biotypes are often comparatively minute. It is not necessary to postulate many mutations, but with the presence of but a few the origin of many true-breeding strains may be accounted for.

[e] It is interesting to note that Le Couteur and Shirreff had modern ideas regarding pure lines, at least for the wheat plant. See Darwin, Animals and Plants under Domestication, vol. I, p. 327. It was reserved for Johannsen to make the idea common property.

In certain brilliant reseaches, Nilsson-Ehle[f] has found that artificial crosses between strains of wheat, apparently identical in regard to certain characters, have developed strains that breed true, showing a differentiation of the characters in question. The true-breeding strains may approximate each other so closely that the various characters would ordinarily be taken as mere fluctuations within a very close variety.

In another experiment, white and brown-eared wheats showed a dihybrid splitting. Thus, by crossing, four constant races could be produced. With certain characters, the visible races would be limited to three. With other wheats, in regard to grain color, the splitting was found to be trihybrid in character, so that from one union eight constant potential races were found, each differing in its gametic makeup. With certain characters, a regular series would be formed, passing insensibly from one extreme to the other. Thus from a cross with trihybrid splitting, eight homozygous strains could result forming a series simulating fluctuating variations. These statements show us that only a few characters need be present originally to produce by crossing an almost endless variation. The occasional field crossing is probably sufficient to bring about in the course of time large percentages of the variations to be found, assuming that we start with a few differing individuals.

RELATIONS TO HARDINESS

The speculative relation of these facts and assumptions to hardiness will now be indicated. We may assume that hardiness is conditioned by certain physical factors, be what they may, and that not all such physical factors are present in one plant. For the sake of argument we may consider that thickness of the cell wall, density of the protoplasm, and what not, are the characters involved. By crossing the plants with the different characters we would in some instances obtain an increase of hardiness, a real increase from what was originally present in any of the strains. Let us take the two hypothetical strains indicated above, each one of them bearing hardiness; with the unit of hardiness in each strain conditioned, in one case by the thick cell wall, and in the other by the dense protoplasm. From a basis of fact, our examples may be ill chosen, but this does not matter. They answer well enough from the stand-

[f] Kreuzungsuntersuchungen an Hafer und Weizen. Lunds Univ. Ars., 1909. Über Entstehung scharf abweichender Merkmale beim Weizen. Ber. Deut. Bot. Gesell., 1911.

point of argument. If these two strains follow the ordinary Mendelian laws in respect to the characters noted, then the worker ought to be able to secure a progeny strain bearing the two physical characters in question, thus obtaining a wheat with greater hardiness than was possessed by either of the parent strains. It might require the crossing of several strains to obtain the maximum result. The writer developed this idea independently,[g] but later found that Nilsson-Ehle[h] had previously worked out the hypothesis. Nilsson-Ehle states that assuming this to be true we would have an accounting, in part, for a gradual increase of hardiness in the field, assuming a certain amount of field crossing to take place.

Nilsson-Ehle has shown that cereals which have comparatively slight characters, such as we would commonly consider as marking off biotypes, Mendelize with as much certainty as characters that bulk larger or are more distinct. In a recent contribution, Pearl and Bartlett[i] have found that chemical characters of varying degrees are evidently inherited along Mendelian lines. They worked with certain chemical characters, but it would seem that their results might be applied from an *a priori* standpoint to slight morphological features. Assuming this it might not be difficult to find comparatively many physical characters responsible for hardiness, which would individually Mendelize.

While the idea that hardiness is carried by certain physical characters which Mendelize upon crossing may be theoretical and may have no basis in fact, the economic importance of any increase in hardiness in winter wheat is so great that it would seem well worth while to do considerable work in crossing various strains looking towards the idea of developing a strain of fall wheat somewhat hardier than any now existing. It is apparent that for the present, until we gain more knowledge, the crossing would have to be hit-and-miss and it would only be by luck that we would be able to strike a successful crossing. If it were possible to secure positive results there is no reason to suppose that the hardier strains should not be developed as quickly from reasonably closely related parent strains as from more widely related ones. The writer has started work of this nature and in 1911 made, or had made, crossings of over 3000 individual wheat flowers. The F_1 generation of these is now in existence (December, 1911).

[g] Waldron, L. R., Third Annual Report, Dickinson Sub-exp. Sta., p. 33, 1910.

[h] Nilsson-Ehle, Kreuzungsuntersuchungen an Hafer und Weizen, p. 114.

[i] Pearl, R., and Bartlett, J. M., The Mendelian Inheritance of Certain Chemical Characters in Maize, Zeit. f. Indukt. Abs. u. Vererbungs., vi, p. 1, 1911.

It may be nothing more than a mere coincidence that alfalfa and fall rye, which seem to be much more adaptable from the standpoint of hardiness than fall wheat, are more or less open pollinated plants. If one were able to discover a few mutations of fall wheat with as strong a tendency for open pollination as fall rye, would such strains show cumulative hardiness in comparison with the ordinary strains of fall wheat, which do not cross in the field? The question is at least interesting, even if unanswerable.

DELIMITATION OF FALL WHEAT AREAS

Before leaving the subject of fall wheat let us delimit for a restricted region those areas, as nearly as possible, of successful and non-successful fall wheat culture as they occur in the cold Northwest. The data can be considered only in their broader aspects.

Over considerable portions of the plains region of Montana, winter wheat seems to be an unqualified success; but at Dickinson its successful culture, at the present time, is practically impossible when given the same cultural methods as are given it in Montana. In neither case is injury to the fall wheat brought about by the alternate freezing and thawing of the ground, producing the "heaving" so common in many of the humid states, and only very rarely is injury brought about either in Montana or at Dickinson by the smothering effect of long-continued covering of snow.

The character of the winters is much the same in Montana and at Dickinson. The snowfall in both instances is comparatively light, speaking now of the plains area of Montana. And in both cases, also, more particularly in Montana, is the snow covering likely to become lost at different periods during the winter by means of "chinooks." In both cases rather extreme drops of temperature are not uncommon during the winter.

We have authentic yields of winter wheat at Forsyth, Glendive, and Dickinson, the same variety, Turkey Red, grown under similar cultural methods. As stated, fall wheat at Dickinson has been a failure except one year, when only a partial failure was recorded with an unusually heavy snow covering. Fall wheat is considered more successful at Glendive than at Dickinson, though at Glendive killings occur, but upon the other hand, however, excellent yields have been secured. At Forsyth the success of fall wheat seems to be complete.[k]

[k] Atkinson, Alfred, and Nelson, J. B., Mont., Bulletin 83, 1911.

Glendive lies 86 miles west of Dickinson and 12 miles north Forsyth lies 180 miles west of Dickinson and 30 miles south. The precipitation for the three points runs comparatively close. The slight difference in winter precipitation is by no means great enough to account for a complete success of wheat upon one hand and its complete failure upon the other. The key to the situation seems to lie with the temperature. The winter temperatures are as follows, for the three points:

Temperature in degrees Fahrenheit.[l]

Station.	January	February	November	December
Dickinson	10.7	11.7	27.6	18.1
Glendive	13.6	12.8	29.5	18.9
Forsyth	17.7	17.3	35.7	23.6

There is a gradual increase in winter temperature as one passes from Dickinson to Forsyth. The average temperatures for the three coldest months, January, February and December, for the three points are as follows: Dickinson 13.5°, Glendive 15.1°, Forsyth 19.5°. The differences of temperature probably account for the success or non-success of the fall wheat in the different localities. It is to be hoped that within the next few years a fall wheat may be secured so hardy that it may be depended upon for regions having winters as severe as those at Dickinson. But if such a thing should happen it is quite likely that in the end we would still be considerably in the dark as to the exact method of its origin.

In this regard, it is well to note that the improved fall wheats that are successful in Montana, upon the borderland of their successful existence, are not those that have had their hardiness increased in this country by a period of unconscious breeding running through one or two human generations, but are Russian wheats imported quite recently; the Turkey Red, and its improved strain, the Kharkov.

HARDINESS OF ALFALFA

Our investigations regarding the hardiness of alfalfa have been more extensive than those of winter wheat. The studies are still under way and, in part, have been reported.[m] As stated, alfalfa is seem-

[l] From published data of the Weather Bureau.

[m] Brand, Charles J., and Waldron, L. R., loc. cit.; Waldron, L. R., Second Report on Cold Resistance of Alfalfa, Seventh Ann. Rpt. Am. Breeders' Assoc.

ingly more adaptable relative to hardiness than fall wheat. A partial explanation of this has been suggested in that the plant is more or less open-pollinated. We have found that strains of alfalfa from regions of the south contain elements which persist through extremely severe winters. These when propagated sustain their good record in large measure.[n]

The effect of *Medicago falcata* upon hardiness in ordinary alfalfa when present has been investigated to some extent.[o] It has been found that most alfalfas now grown in continental Europe contain some admixture of *Medicago falcata*.[p]

The majority of such plants are very close to *Medicago sativa*, but a certain proportion of the flowers are variegated in color. An effort has been made to determine if this amount of variegation is correlated with hardiness. The results were negative, as variegation did not seem to be correlated with hardiness. However, certain strains of *Medico falcata* are certainly very hardy, and from a crossing between them and *Medicago sativa* one would expect a portion of the offspring to be hardy. To determine this is apparently a matter for future investigations. There is no question that the Grimm alfalfa is, comparatively speaking, exceedingly hardy. Whether this hardiness is due to the comparatively small amount of *Medicago falcata* blood which the variety contains, or whether this has had no effect upon increasing its hardiness, cannot be determined from the data at hand.

RED CLOVER

Hardiness in red clover has apparently received but little study, at least in this country. Apparently it does not have the wide range of adaptability found in alfalfa. Though the plant is pollinated by insects, the writer is not aware that we have accurate knowledge of the amount of crossing that naturally takes place. Even if commonly open-pollinated, perhaps there are no *a priori* reasons why the plant should have a wide range of hardiness.

There is no question that the practical and scientific problems having to do with the increase of hardiness in certain of our agricultural plants are of the very greatest interest and importance. Some good scientific work along these lines will not only throw a flood of light upon problems of development, but practical results will accrue in no small measure.

[n] Data shortly forthcoming in *American Naturalist*.

[o] Westgate, J. M., Variegated Alfalfa. Bulletin 169, Bur. Pl. Ind., 1910.

[p] Waldron, L. R., Variegation of European Alfalfas. Science, N. S., xxxiii, p. 310, 1911.

BREEDING EXPERIMENTS WITH FORAGE PLANTS IN FLORIDA

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The Florida velvet bean (*Stizolobium deeringianum* Bort) is grown for forage or green manure over more than 30,000 acres in Florida, as well as in several other states. One of its best qualities, which is shared by some other species of the genus, is its freedom from root-knot. An allied species, the Lyon bean (*Stizolobium niveum* (Roxburgh) Kuntze), from the Philippines, has desirable qualities which make some farmers prefer it to the velvet bean, and its cultivation is being extended. A third species, the Yokohama bean (*Stizolobium hasjoo* Piper and Tracy), from Japan, has the advantage of much earlier ripening, but its hulls are excessive in weight. Since each of the three has its good and bad points, experiments are in progress to determine whether the good points can be combined in different was in severaly homozygous strains, which will be of use for different purposes in different localities.

The hybrid (or F_1) generation of the cross between the velvet and Lyon has a vigorous and rapid growth, with large leaves and shoots. The purple of the velvet bean is dominant in the flowers, the leaf-axils, and on the under side of the first simple leaves. The length of hairs on the pods, and the mottling and thickness of the seeds are also dominant characters derived from the velvet bean. The undulation of the leaves, the long racemes, the long pods, the long and broad seeds, and the stiff hairs on the pods and young shoots are dominant characters from the Lyon. The reciprocal crosses, velvet by Lyon, and Lyon by velvet, seem to give the same result in F_1.

In the segregate (or F_2) generation, there is a complex segregation of earliness and lateness, more than one-seventh of the plants (317) flowering before the Lyon and velvet (which do not differ much in this respect), and more than one-seventh not flowering at all before frost. This is confirmed in F_3, late-flowering being recessive.

The hairs on the pods (which are important because the beans when not used for forage are picked by hand) segregate in a complex manner (I am at present working with three factors) into long stiff, intermediate stiff, stiff and velvet, long velvet, short stiff, and short velvet, and some minor grades. The velvet is usually black, the other hairs

are colorless, yellow, or brown. The long stiff hairs are irritant, and must be excluded in breeding forage plants.

The lengths of the pods segregate into long and short, with intermediate grades. Some of the plants have pods shorter than those of the velvet, and others have pods longer than those of the Lyon bean. This is also the case in the F_3 generation. The shortness of the pods is recessive. Plants with seeds too long for the pods, which seeds are therefore much flattened by mutual pressure, have been grown in F_2 and F_3. In none of the segregates were the hulls so weighty, in proportion to their seeds, as in the Yokohama bean.

The opening of the pods after ripening, which is so marked in the Lyon, and from which the velvet bean is nearly free, is a dominant character, occurring in different degrees in three-quarters of the F_2 generation.

The average numbers of beans in a pod, which are nearly the same in the velvet and Lyon, vary greatly in the F_2 generation in both directions.

The total crop of each plant (F_2) varies far more than do those of Lyon and velvet beans grown in the same field. A crop of only a few beans on large vines appears again as a recessive in F_3.

Two factors at least are apparently concerned with length of seed. As in the case of pod length, plants with seeds shorter than the velvet, and others with seeds longer than the Lyon, appear in F_2, and again in F_3.

The average breadths of the seeds of the F_2 plants have a correlation with their lengths of 0.87 ± 0.02. But breadth is not simply proportional to length, for many plants have relatively broader or narrower seeds. It may be that the factor or factors for breadth segregate, and influence the proportionality of length and breadth only to a certain small degree. This is being tested with the F_3 generation.

Of the thicknesses of the beans, much the same may be said as of the breadths, except that the thickness show more "modification" (Baur) and hence are less suitable for mathematical treatment.

The Lyon bean has white seeds. The velvet bean bears seeds with one-half or less of their surface covered by a fairly definite pattern of blackish-brown mottling. In the hybrid (F_1) generation the mottling is spread over more of the seed, and is only about one-half as deep in hue. The heterozygous seeds are also subject to modifications, causing all the seeds of a pod or raceme to be much less mottled, or even pure white. There is no genetic difference in mottled and white seeds of the F_1 generation. In the segregate generation the same

spreading and modification of the mottling occur in many plants. Out of 118 F_2 plants which produced abundant seeds, there were 116 mottled in different degrees (from nearly total to a few small flecks), and 2 pure white. This shows the probability of three independent factors for mottling. The F_3 mottled and white are at present being studied.

The work has shown that not only could the desired combinations be obtained in F_2, but that unexpected valuable characters, such as earliness and larger seeds, might also occur. This year (1911) was a late season, and an early frost caught my Lyon and velvet beans on poles, while certain selected F_3 segregates, planted with them, had already ripened and dried out all their seeds and pods.

ASPARAGUS BREEDING

J. B. NORTON

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Asparagus officinalis has been grown as a cultivated vegetable for thousands of years, and, so far as I can find in literature, has never been bred in a systematic manner. The early Roman civilization left records of stalks that weighed more than 5 ounces, and we have gone little beyond that at present. There is no definite record of its introduction into this country, but it has established itself as a wild plant all over the country, and has been grown as a truck crop for nearly fifty years. Numerous American strains have been named and are well known in Europe.

The accidental introduction of asparagus rust from Europe in 1896 changed the whole situation, and for a time it looked as though the crop would be a thing of the past.

After ten years of effort on the part of the pathologist to fight the disease with partial success in California, the Bureau of Plant Industry was appealed to by Massachusetts growers to undertake breeding experiments based on the already known resistance of some of the European forms of recent introduction. This work was undertaken by Messrs. Shamel, Oliver, and W. W. Tracy, Sr., and it was through their joint efforts that a collection of known European and American named sorts were collected as a basis for selection work at Concord, Mass., where the work is carried on in coöperation with the Massachusetts Experiment Station.

The writer's connection with the work dates from the fall of 1908, when it was deemed advisable to start individual selection work. That fall the plants on the station grounds were gone over and marked for comparative rust resistance.

The fact that asparagus is diœcious made it necessary to mark plants of both sexes. Seed was saved from a number of plants of different degrees of resistance and from different strains in order to make preliminary tests as to transmission of resistance. At the beginning of the work it was recognized that vigor must be taken into account. Careful growers contradicted the evidence of the pseudo-scientific statements that vigorous plants are resistant. With this in mind only those plants having both vigor and resistance were selected from about five acres of resistant strains. The location of these plants was marked on maps of the fields for re-location the next spring.

In 1909 the plants that had been marked as resistant in 1908 were allowed to grow in the spring, while all other plants were cut for market. Hand pollinations of as many different combinations as possible were made during the blooming season. The best female plants were used to test as many males as possible, and the best males were used to check the transmission of the female plants. The hand pollinated seed and comparable open fertilized seed were saved for tests in 1910.

New selections were made in the fall of 1909 for rust resistance on about ten acres, the 1908 selections of the best type all reappearing in the 1909 resistant lot. This fact showed that resistance belonged to the plants as an individual permanent character and was probably heritable.

Tests in 1909 were made on 1908 open-fertilized seed. The resistance of the sixteen lots tested was almost exactly in the same order as the individual resistance of the parent plant. This practically settled the breeding proposition, and from that time the writer has had no doubt of the final outcome.

Among the interesting developments of 1909 was the discovery of several hermaphrodite plants. In every case the plants were male types with occasional fruits developing from apparently normal male flowers which always have a more or less perfect ovary. Experiments are being carried out on the inheritance of this character but no results of importance have developed.

Several yellow-berried plants were found, but as yet we have no seedlings in fruit from them. The inheritance of purple or "green" shoots compared with light green or white is also being studied. There

is a variable intermediate F_1 probably due to a complex of color genes, and to a heterozygotic condition of the parents.

In 1910 eleven hundred seedlings of different lots were started in the greenhouses at Washington in January and transplanted into the fields at Concord later on in May. The remainder of the seed was planted in seed beds in the experimental grounds.

These greenhouse seedlings were studied carefully as to relation of parents to size, vigor, etc., seed size in relation to plant size while in the greenhouse. After making the transfer to the field, careful studies have been made of rust resistance, height, size, vigor, etc.

The work of 1910 settled beyond all doubt that there was great difference in the transmission of vigor, rust resistance, and type in the different parent plants used. One male was found of superior merit "prepotent" in rust resistance and vigor. No matter what female was used in mating, the offspring with this male (7–83) showed great resistance, varying, however, according to the resistance index of the dam.

The combination with 32–39 showed great resistance and, although in no case have we secured plants immune entirely, this progeny is satisfactory to the interested growers and will be produced as a commercial strain—a pedigreed progeny.

The work of 1911 was a continuation and duplication of the work of the preceding seasons, new selections being tested by hand pollination and new resistant plants marked for future tests. In 1910 and 1911 7–83 was used to test new female plants; in 1910 a few other males were used, but the 1911 seedlings showed the great superiority of 7–83 over all others so far found. None of the progeny of 7-83 have tested offspring yet, but as the rust resistance transmission is strongly correlated with individual immunity it is fully expected that some will be even better than the parent male. The season of 1912 will show this and settle several other questions of importance.

METHODS

In carrying out this work several things have been used that may help other breeders. The use of insulated copper wire instead of string or plain wire has saved much time in fastening on bags. Common office wire is used, cut into convenient lengths with a pair of shears, and when bent around a bag over a flowering branch holds permanently without cutting either the very tender stem or the damp bag. This wire is also invaluable in greenhouse work and in the field

as a supporting tie: quick and easy in application, it never cuts or wears.

The transparent bags used in our work have already been described before this association and are invaluable in asparagus work, where we have to cover up the foliage as well as the flowers. Cages of fine wire screen are used where it is desired to pedigree all the seed a plant produces. The males have to be protected, as the bees rob all the flowers early in the day unless they are kept away. Common fly screen is not fine enough, as there are small bees that can get through the meshes. Geographic isolation will be used to secure large quantities of seed from one male in combination with one or more females.

Instead of growing seed from progeny plantings, the original plants that give the desired progeny tests will be numbered and named, propagated vegetatively and planted in breeding blocks isolated from any other plants by distance and intervening obstacles. The males will receive common family names, as No. 1—Wilson, No. 2—Wheeler, etc. The females will be given feminine names, as No. 101—Mary, No. 102—Ida, No. 103—Priscilla, etc. The progeny names will then become fixed, easily remembered combinations, as Mary Wilson, Ida Wilson, or Priscilla Wheeler, and under these names will be handled by the trade. When any grower sells mixed F_2 stock from any of these progenies it will have to go as "Mary Wilson stock" or "Priscilla Wheeler stock" to distinguish it from the pure F_1 progeny pedigreed direct correlation.

The question of the value of any character as a basis of selection for any other character has come up strongly in this work, and also the value of a selection one year in its relation to future seasons. What effect does the size of seed have on plant size? Can we tell by any character of a seedling whether it will be a good plant, etc. These queries have caused considerable work on correlation, and the work has proved some interesting facts, which are brought out in the following tables. One point of general interest to the breeder at large is the use of the tallest plant in a normally variable lot of seedlings to show the average of the lot. This is a great labor saving device in making a large number of elimination selections.

The use of height in the seed bed to indicate size in succeeding years is the only hope the asparagus breeder has when handling large numbers, as the rust elimination of the future will be done in the seed bed—the early work planned, selection of size first and resistance afterward, but this requires an acre to 5000 plants, while by my new test system we can test the progeny of 5000 plants on an acre. The

seedling test is far and away ahead of the old plant test, as we get uniform conditions, strong infection, and immediate results.

The relation of seed size to seedling size is going to bother right through the work, as small seed do not get away anything like as fast as large seed, and in many good resistant plants the seeds are small.

The relation of amount of fall growth to next year's yield is very important, as the rust selection is based on fall conditions and then many plants must not be cut, as they have to be used for seed purposes. This correlation is so high, however, that any spring selection can be omitted except for type.

In the course of the work it has developed that yield is the big factor to work for, as the gradual elimination of the old American varieties by the new semi-resistant European strains is reducing the rust problem in the east. The saving feature of our work is that the best male in resistance is by far the best in transmitting vigor.

LONGAVINBO AND THE MUTATION THEORY

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Following is an account of a composite hybrid of six species of grape with steps in its production and results in each successive combination.

ANALYSIS

Longavinbo	= Solincrup × Brilliant.
Solincrup	= *Vitis longii* (selected) × Male 70.
Male 70	= Jaeger No. 70 × Male *Vitis rupestris* (selected).
Jaeger No. 70	= Jaeger No. 43 *Vitis lincecumii* (best selected of Missouri) × Male *Vitis rupestris*.
Brilliant	= Lindley × Delaware.
Lindley	= Carter (a very large-berried *V. labrusca*) × White Chasselas (vinifera).
Delaware	= (supposed) Catawba × Elsingburgh (*V. bourquiniana*).
Catawba	= *Vitis labrusca* × *Vitis vinifera* (supposed accidental hybrid).

Hence the proportions of specific blood in Longavinbo are:

Vitis longii (variety Hutchinson)	4/16
Vitis lincecumii, Jaeger 43	1/16
Vitis labrusca, Carter and unknown	3/16
Vitis rupestris, male seedlings of No. C0	3/16
Vitis vinifera, White Chasselas, and unknown	3/16
Vitis bourquiniana, Elsingburgh	2/16
Total	16/16

SHORT DESCRIPTION OF EACH SPECIES

Vitis Longii, variety Hutchinson.—Native in the canyons and ravines of Texas Panhandle. This variety came from Hutchinson County, Texas. Can endure 30° below zero and much heat and drouth, resists mildew and rot well, grows easily from cuttings. Nearest ally is *V. vulpina.* Clusters 2 to 3 inches long, very compact; berries $\frac{1}{3}$ to $\frac{1}{2}$ inch in diameter, black; skin thin, tender, but never cracks, much violet coloring in the juice; pulp tender, quite rich in both acid and sugar, of pure sprightly vinous quality, flavor similar to *V. vulpina* and more pronounced.

Flowers self-sterile leaves medium to small, bearing little hairy down on either surface. Resists Phylloxera well.

Vitis Lincecumii, variety Jaeger's No. 43.—Found native in southwestern Missouri. Can endure 30° below zero, also great drouth; difficult to grow from cuttings. Nearest ally is *V. æstivalis.* Clusters 5 to 7 inches long, cylindrical, with shoulder, very compact; berries $\frac{1}{2}$ to $\frac{5}{8}$ inch in diameter, black; skin rather thin but does not crack, red color in skin and juice, pulp juicy, tender, of good quality, and of peculiar agreeable flavor. Flowers self sterile. Leaves large dark green above, bluish green below, with very little scattered hairy pubescence, lobed. Resists Phylloxera well.

Vitis Rupestris.—Varieties used were male seedlings of Jaeger No. 60, an especially good variety, native of southwestern Missouri. Can endure 30° below zero, considerable drouth, and is immune to mildew and rot; roots very freely from cuttings. Its nearest ally is *V. longii.* Clusters 2 to 3 inches long, shouldered, less compact than *V. longii;* berries $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter, black without bloom; skin very tender, black; pulp melting, pure vinous with a distinct, delicate flavor, very highly colored, with abundance of violet juice. Flowers of wild females self-sterile. Leaves small, smooth on both surfaces, pale yellowish green, often with a metallic luster on upper surface, rarely lobed, the sides folding partly together, the midrib being the line of fold. Very resistant to Phylloxera.

Vitis Labrusca.—At least two different female varieties of this species entered the Longavinbo, but the description of neither is known, so I give a short, partial, general description of the species. This species from Carolina, where the Catawba originated, can endure 15° to 20° below zero, and in Massachusetts, where Carter was found, it endures as low as 35° to 40° below zero. It is a shallow rooter and hence suffers from heat and drouth, but it resists mildew and rot well;

roots from cuttings freely. It has a tendril opposite every leaf in well grown shoots; this no other species has. In all other species every third leaf has no tendril. It is distantly related to other species, finding its nearest relatives probably in Asia in the *V. davidii* and *V. coignetiæ*. Clusters 2 to 5 inches long, shouldered, compact; berries ½ to 1 inch in diameter, globular or ovate; skin thick, tough, usually black; pulp tough, oyster-like, juicy, and very "foxy" in flavor and odor; quality poor, lacking sugar, seeds large. Flowers of wild or native (not cultivated) varieties self-sterile. Leaves large, leathery, dark green, wrinkled upper surface; lower surface densely felted with a brownish short pubescence; slightly lobed, opening out flat. Concord, Ives, Champion, Hartford are best known cultivated representatives coming from the woods of the Northeastern States. This species is low in resistance to Phylloxera.

Vitis vinifera.—This is the cultivated grape of Asia and Europe. The White Chasselas is similar to the Sweetwater, with larger berries. It, crossed on the brownish Carter (*labrusca*), gave the Lindley, a red grape with self-sterile flowers, taking after its mother, as the White Chasselas (its father) had hermaphrodite flowers, self-fertile. Catawba must have had either a red or white hemaphrodite Vinifera parent united with probably a black *Labrusca*. Viniferas are all subject to mildew, rot, phylloxera, and endure temperature little below zero, but much heat and drouth. Leaves small to medium, lobed, little pubescence; widely separated from other species.

Vitis bourquiniana.—Supposed to have pollinated Catawba to give Delaware. Is found in the Elsingburgh, which has vine, leaf, and cluster much as in Delaware but with black, small berries, though with colorless juice. It resists Phylloxera well.

Jaeger No. 70.—This is a very vigorous, branching vine, about midway in characters between its parents. This pollinated by a male seedling of *V. rupestris* gave me among others a very vigorous male vine (Male 70), much resembling the mother, but stronger every way, the flower cluster being very large, and abundant in well developed pollen, which I used in pollinating a select vine of *V. longii*, named Hutchinson, from the northern part of the Texas Panhandle. Of the numerous progeny of this pollination I selected one variety having the best and most abundant fruit and named it Solincrup (the name being made up of syllables of *solonis*, *lincecumii*, and *rupestris*, denoting its combination—*solonis* × (*lincecumii* × *rupestris*)). There was much variation among these three-species varieties, from close resemblance to *rupestris* to close resemblance to *solonis*, with little

reminder of *lincecumii*. Solincrup appeared to be about an even mixture of *solonis* and *rupestris*, but the clusters and berries were larger, evidently the effect of *lincecumii* blood contained. The clusters were very compact, when properly pollinized (the variety being self-sterile), the berries jet black, with little bloom, skin very thin and tender, pulp melting, high in sugar and acid, capable of making a fine wine, flavor more like *solonis* than *rupestris*, juice intensely violet colored, seeds below medium; vine vigorous and healthy.

Brilliant.—The Brilliant was made by me, by pollinating Lindley, a fine, large, brick-red self-sterile variety, produced by Rogers, with pollen of Delaware, a self-fertile, translucent, red variety whose prime origin is unknown but supposed to be a cross of Elsingburgh (*bourquiniana*) upon Catawba, both hermaphrodite, self-fertile varieties, Catawba red, Elsingburgh black. Brilliant in leaf and vine, is much more like Lindley than Delaware, but in fruit is pretty near an even blend, with a more tender skin and pulp than either parent, and a most delicious eating grape, vigorous and prolific; leaves rather large, considerably downy on lower surface—from its *labrusca* blood—and tendrils generally continuous—also labruscan—but in fruit much more like *vinifera* than any other species. Flowers self-fertile. Leaves, like those of both parents, subject to mildew, but fruit nearly immune to black rot, roots weakly resistant to Phylloxera.

Longavinbo.—Upon Solincrup I applied Brilliant pollen, and among many greatly differing varieties resulting I selected one seeming to embody the most even mixture of all the elements contained, and named it Longavinbo.

Longavinbo is a name made by uniting one or more letters taken from each of the specific names of grapes entering into its composition as a variety, and befits it as a complex conglomeration (*LONG*ii-l*A*brusca-*V*inifera-rupestr*I*s-li*N*cecumii-*BO*urquiniana). It is characterized as follows: It has endured 15° below zero without injury and probably can stand 25° to 30° below; resists heat and drouth excellently; resists Phylloxera, mildew, and rot almost entirely, cuttings root freely and very vigorously, vine strong and prolific; clusters 4 to 6 inches long, conical, not very compact; berries $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter, spherical, black with little bloom; skin thin, but does not crack; pulp tender, juicy, rich in claret-red color; quality very good, sprightly, rich in sugar, and abundant in acid; makes fine red wine of excellent keeping qualities; fruit markets as well or better than Concord, berries persistent; keeps well, ripens in midseason; has no trace of foxiness; flowers hermaphrodite,

self-fertile, leaves medium, little lobed, a little scattering cottony pubescence on lower surface; tendrils intermittent.

This variety should yield great variation, among its seedlings, toward some one or other of the species involved. Its capacity as a breeder of good varieties has not been tested. It is the product of the generations of combinations of older combinations and newer species as outlined in the foregoing by the writer and it is not yet disseminated.

These facts are given to show that mutation to forms outside the species contained does not occur as maintained by DeVries, giving rise to new distinct species. In all my work of producing many thousands of seedlings and hybrids in each of no less than 17 distinct species of grapes no such mutations have occurred, but the forms are always conglomerates of what have been united.

It is a result without a cause to have a form clearly distinct from either parent entering into a combination to come out and continue to reproduce itself. The fact of great variation among seedlings, according to the Mendelian law of heredity and my experience, so far as it goes, always indicates mixed blood in the parents. To assume that nature sometimes (as claimed by DeVries with Oenotheras) leaps at one bound into an entirely new specific form, unlike anything that had before existed, is unscientific and defies all the known laws of heredity, and of cause and effect. Monstrosities cannot be cited as such mutations, as they do not reproduce themselves, and so far as known have specific immediate causes, such as a pumpkin growing between fence rails.

Since writing the above, I have grown over 500 seedlings of Longavinbo, now, July 2, 1912, from 12 to 24 inches high. The vine bearing the seeds stood where it could receive pollen from no other species than those contained in itself, except a male vine of V. candicans, which stood about 100 yards distant and bloomed at same time. The vine was in no way protected from intrusion of pollen from surrounding vines. The seedlings are a motley lot, yet only one of them shows other blood than what the mother vine is known to contain, except one which clearly shows V. candicans to the extent of at least one-half. All the species contained in the mother can be easily recognized cropping out in the seedlings; not all in any one seedling, but much of some one species in some of the seedlings, and of other species in other of the seedlings. No variations to new and heretofore unknown species occur although such a broken up condition of specific bloods, would seem most favorable thereto, if such is true in any case.

THE BRANCHING CHARACTER IN FLAX

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In the production of flax (*Linum usitatissimum*) two types receive commercial recognition, fiber flax and seed flax. A non-branching type is desired in growing fiber. In producing seed fewer plants are grown per unit of area, and branching is encouraged. The fiber grower sows from 2 to 3 bushels of seed per acre. The seed grower may sow half a bushel or less. The producers of fiber know that the thickly seeded flax which produces one stem per plant gives the best fiber. Yield of grain is a minor consideration. It has been assumed that the branching character is associated with yield, although so far as the writer is aware no data on this point have been published. Does a many branched plant produce more seed than one with few branches? Information on this subject should throw some light on the problem of thick and thin seeding. It should be of especial value to the flax breeder who attempts to make field selections of high-yielding plants.

MATERIAL STUDIED

In an effort to study the relation of the physical character of branching with yield, four kinds of material were examined.

(1) *Centgener stock—Fiber.*—205 individuals grown in centgeners during the years 1905–6 and 1909. These plants were selections from a strain known as the Riga Fiber flax, the seed of which was imported from southern Russia in 1897. It had been grown in the nursery since 1901. There were 100 plants in a centgener planted 4 inches apart, and each year data were taken on four plants. Twenty centgeners were involved.

(2) *Centgener stock—Seed.*—231 individuals grown in centgeners during the years 1905–1906 and 1909. These plants had their origin in two sources. Forty-seven centgeners were studied. Twenty-two were from a field selection made by Professor Hays in 1895 and 25 from a selection made by Professor Ten Eyck in 1900. Like the plants in the first lot, they have been carried along in the nursery since 1901 at the North Dakota Experiment Station.

(3) *Mixed population—Greenhouse.*—173 individuals from twenty-six sources in the United States and Canada were grown in pots under glass during the winter of 1911 at Cornell University, Ithaca, N. Y. Less than a dozen of these plants could be recognized as fiber types.

Flax does not adapt itself well to greenhouse conditions, and the yields per plant were low, although a maximum growth of straw seemed to be reached.

(4) *Mixed population—Field.*—345 individuals grown under field conditions during the summer of 1911 at Fargo, N. D. One-half bushel of seed was sown per acre in 6-inch drills. About four plants per linear inch comprised the stand. This seed was from a selected strain bred for resistance to wilt and was known as N. D. No. 52.

BRANCHING CHARACTER

A wide variation in the number of main stems or branches was found. Table 1 shows the distribution.

TABLE 1.—*Frequency distribution of branches in four flax populations.*

Number of branches.	Centgener stock, fiber.	Centgener stock, seed.	Mixed population, greenhouse.	Mixed population, field.
1	15	12	....	177
2	24	4	....	103
3	65	82	41	57
4	12	55	15	4
5	14	38	25	4
6	15	21	20	....
7	10	9	33	....
8	18	4	18	....
9–20	32	6	21	....
Total..........	205	231	173	345

So far as the centgener stock is concerned unconscious selection has rendered much of the data valueless in correlation work. Studied from the standpoint of the individual plant, however, the relation of the branching habit to yield is suggestive. Table 2 shows the average number of seeds per plant in the four sources of material.

TABLE 2.—*Average number of seeds per plant in four flax populations.*

Number of branches.	Centgener stock, fiber.	Centgener stock, seed.	Mixed population, greenhouse.	Mixed population, field.
1	239.6	754.8	....	96.9
2	255.3	613 3	....	116.7
3	288.8	521.7	77.6	170.1
4	309.3	706.0	79.1	348.5
5	226.5	633.1	154.4	208.5
6	122.9	586.8	110.8	....
7	102.7	461.4	129.2	....
8	97.2	594.0	88.9	....
9–20	131.4	965.7	93.2	....

An interesting circumstance is brought out by a study of this table. Ignoring those classes with a very small number of plants, it is seen that the three branched plants of the field stock yielded best, the four branched plants of both centgener stocks produced the most seeds, while the five branched individuals which had the most favorable opportunities for growth were the highest producers. (Table 3.)

TABLE 3.—*Average weight in grams of seeds per plant in four flax populations.*

Number of branches.	Centgener stock, fiber.	Centgener stock, seed.	Mixed population, greenhouse.	Mixed population, field.
1	0.694	2.959	....	0.394
2	0.923	2.550	....	0.489
3	1.093	2.416	0.222	0.670
4	1.008	3.124	0.221	1.424
5	0.914	2.837	0.409	0.844
6	0.623	2.876	0.309	....
7	0.550	2.189	0.349	....
8	0.467	2.775	0.244	....
9-20	0.652	4.383	0.300	....

The fiber stock produces a greater weight of seed in the three-branched type but a greater number of seeds in the four-branched plant. Table 4 shows the average weight in grams of 100 seeds from each class of the four stocks.

TABLE 4.—*Average weight in grams of 100 seeds from four flax populations.*

Number of branches.	Centgener stock, fiber.	Centgener stock, seed.	Mixed population, greenhouse.	Mixed population, field.
1	0.2894	0.3919	....	0.4065
2	0.3616	0.4158	....	0.4192
3	0.3782	0.4631	0.2855	0.3948
4	0.3261	0.4424	0.2789	0.4085
5	0.4037	0.4481	0.2647	0.4002
6	0.5071	0.4902	0.2783	....
7	0.5356	0.4744	0.2699	....
8	0.4803	0.4672	0.2745	....
9-20	0.4964	0.4539	0.3223	....

Considerable variation in weight is found in the various classes. In general the many branched plants produce a heavier seed. Several factors which have a direct bearing on selection stand out prominently in a study of these data.

(1) A variation in the number of branches ranging from one to twenty.

(2) The branching habit can be easily controlled by planting. Thick sowing causes little branching.

(3) Excessive branching lessened the number of seeds and the total weight of seeds per plant.

(4) Excessively branched plants in the centgeners produced a heavier seed than little branching types. The difference was negligible in the mixed populations.

A STUDY OF INDIVIDUAL PERFORMANCE IN HOPS

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One of the problems of the breeder of plants or animals is to produce diversity or variations which may be made the foundation stock of new and improved strains; the corresponding problem of the practical grower is to secure uniformity, that is, to prevent or avoid those variations which tend to lessen the evenness or constancy of his product.

The normal diversity of the hop plant is so great that the breeder is put to little trouble in securing a wide range of variations suitable for his purpose. In fact, the variability of the plants in every field of hops is so great that, as was remarked to the writer by Dr. Fruwirth, of Vienna, there is really no necessity for hybridizing hops in order to secure material for the work of selection and improvement. The practical recognition of this fact is evidenced by the now universally adopted method of asexual propagation, by which the range of variability incident to seed propagation is materially diminished. Nevertheless many characters of a population of individuals produced asexually are subject to great variations which must be taken into account when the plants are considered from an economic standpoint. Some of these may well be mentioned specifically.

Variation in the characters of the vine.—The color of the vine may be green or red, green with red stripes, red with brown dots or whitish-green. In Europe three distinct varieties are based on the color of the vines but in America care has not been taken to observe these distinctions, and in many fields representative vines of each color may be found.

The number as well as the length of the internodes of the vine is also quite variable, ranging in normally developed individuals from 30 internodes, varying in length from 4 to 37 cm.; to 50 internodes,

varying in length from 3 to 34 cm. The average internodal length in the first case was 16.6 cm., in the second 23.5 cm.

In thickness the vine has been found to vary from 0.2 to 1.8 cm.

Variation in the flowering branches.—In some hop plants the strobiles occur singly in the axils of the stem leaves. Also they often occur singly at the nodes of the so-called arms, which are axes of the second degree. When the development is normal what may be termed flowering branches arise from the nodes of the arms, and these in turn may branch successively from one to five or six times. Variations of this class are of great economic importance since there is a direct relation between the degree of branching and the yield.

Variation in time of ripening.—The time of ripening of hops varies widely according to the variety, but in a population consisting of the same variety the range of variation in this respect is great. A very large proportion of the plants ripen at approximately the same time, but occasional individuals are found which are very early or unusually late in ripening. In one season the difference between these early and late ripening plants was found to be forty-two days.

Variation in the strobiles.—The form of the strobile varies from almost spherical or globular to long cylindrical, and all gradations between these regularly occur. The color varies from pale green through yellowish green to pale yellow. The number of bracteoles in normal strobiles has been found to vary from 14 to 53 mm., and the length of the rhachis or spindle from 18 to 42 mm.

Variation in relative proportions of vine, leaves and hops.—The weight of the vine alone has been observed to vary from 29 to 49 per cent of the weight of the whole plant, the weight of the leaves alone from 18 to 43 per cent, and the weight of the hops produced from 8 to 53 per cent.

Variation in yield.—A wide variation in yield will be found in any given population. The minimum record obtained by the writer in 1911 was 0.2 pound per hill, while the maximum was 25.5 pounds. The constants obtained as a result of three years observations are shown in the following table.

TABLE 1.—*Variation in yield, in pounds of hops on one acre.*

	Number of hills.	Mode.	Modal coefficient.	Mean.	Standard deviation.	Coefficient of variability.
1909	853	5.0	7.03	$6.104 + 0.081$	3.539 ± 0.057	57.98 ± 1.224
1910	865	6.0	7 63	5.839 ± 0.062	2.714 ± 0.043	46.48 ± 0.851
1911	887	7.5	5.52	9.290 ± 0.098	4.354 ± 0.069	46.82 ± 0.899

It will be observed that the highest standard deviation, 4.354 ± 0.069, occurred in 1911, which was a very favorable year for the growth and development of the hop plant, while the lowest standard deviation 2.714 ± 0.043, occurred in the previous year in which the plants under observation suffered severely from unfavorable weather conditions and attacks of insect pests. The coefficient of variability, however, for these two years differs by an amount which is less than the probable error. On the other hand the modal coefficient shows a higher degree of conformity to type in 1910 than in 1911.

Some comments may here be made on the usefulness of the coefficient of variability as an index of variation for the problem at hand, although it is realized that the data presented may be criticised since the number of individuals studied is small.

TABLE 2.—*Variation in yield, in pounds of hops according to the number of vines per hill.*

Vines to hill.	Number of hills.	Mode.	Modal coefficient.	Mean.	Standard deviation.	Coefficient of variability.
1	54	1	20.37	1.324±0.115	1.258±0.081	95.01±10.337
2	113	2	16.81	2.597±0.103	1.631±0.066	61.68± 3.672
3	135	5	13.33	4.337±0.132	2.275±0.093	51.99± 2.648
4	186	5	10.21	6.279±0.135	2.741±0.095	43.65± 2.159
5	188	7.5	9.52	7.917±0.158	3.217±0.111	40.63± 1.784
	......	and 8	9.52	......	......	......
6	168	11.0	8.33	8.991±0.152	2.931±0.107	32.59± 1.321
7	8	......	......	......	......	......
8	1	......	......	......	......	......

The plants on the acre on which these observation were made were handled in the manner customary in the production of this crop. Early in the spring all surplus shoots springing up from the crown of the plant are removed, the intent being to leave a definite number, usually 4, sometimes 6, to each hill. A count of the number of vines per hill on one acre at harvest time in 1909 showed, however, that the number varied from one to eight. The individual hills on this acre were then grouped according to the number of vines per hill and the constants for each group determined as shown in table 2.

An inspection of this table shows that the coefficient of variability diminishes progressively as the number of vines per hill increases, and the two apparently stand in a causal relation since the decrease in the coefficient of variability occurs because the mean which is dependent upon the number of vines increases much more rapidly than the standard deviation which undergoes relatively little change. Moreover the modal coefficient decreases as the number of vines per

hill increases, indicating that the type becomes *less conformable* as the degree of variability from the mean yield decreases.

Referring again to table 1 it will be seen however that this relation between modal coefficient and coefficient of variability does not obtain and hence may be assumed to have no significance. But in this case it will be observed that the modal coefficient diminishes as the standard deviation increases, also, with one exception this is true for the data of table 2. In the opinion of the writer this point is worthy of further consideration for an inspection of the frequency distributions for these three years shows that the number of classes in 1909 was 34, in 1910, 28, and in 1911, 42, while the highest frequencies for these years were 60, 66, and 49 respectively. The curve for 1911 is far less steep than that for 1910 and the mode also is less distinct since in a number of the classes the frequencies differ but slightly, although the number of extreme variates is about the same in each case. The effect of this less distinct mode is seen in the relatively large mean which in turn is responsible for the low coefficient of variability. If now we accept as the definition of variability "deviation from type" we must in this case at least consider the standard deviation as the index of variability rather than the usual coefficient. This interpretation, it is believed, is wholly consistent with the observed facts concerning variation in yield in the population studied.

It is not the writer's intention to minimize in any way the importance of the coefficient of variability, but rather to emphasize the fact that it is a measure of relative variation from the mean. However, for the population under consideration, which was fairly homogeneous and consisted very largely of the same individuals in each of the three years considered, it is the actual rather than the relative variation which is of primary importance, and when comparing the yield from year to year, the standard of deviation is certainly the better index of variability.

A consideration, also, of the sharp contrast in seasonal conditions in the years 1910 and 1911 in connection with the data already presented, furnishes additional support to the view that variation in a given population is far greater in a season favorable for the growth and development of the crop in question than in a season in which the conditions are less favorable.

Individual performance.—The data presented in the preceding paragraphs establishes the fact that there is great variation in yield among the plants studied, all of which were grown under conditions which were uniform for each year. It is also evident that each year some individuals gave much higher yields than others, but this knowledge

is of little value as an aid in selection unless the performance of each individual is known for a period of years. In order to secure such a record a plat was made of an acre of hops on which each hill was given a permanent number and the yield of each numbered hill has now been determined for three consecutive years. The constants for this data have not yet been calculated but the record of some of the extreme variants offers suggestions of value. The following tables show the yield of a few of these variants, the number of vines being constant for each hill during the entire period.

From table 3 it may be seen that there was a general depression in yield in the unfavorable season of 1910, although three hills gave a greater yield than in 1909 and two remained stationary. In 1911

TABLE 3.—*Three year record of hills lowest in yield in 1909.*

Hill number.	Yield in pounds.		
	1909.	1910.	1911.
17	5.0	2.5	13.0
61	2.0	1.5	0.5
174	7.5	4.0	6.5
297	6.5	6.0	6.5
319	5.5	11.5	16.5
332	7.5	7.0	17.0
377	7.5	7.5	15.5
474	4.0	7.5	8.0
550	6.0	3.5	6.0
643	7.5	3.5	8.0
669	6.0	5.5	15.0
702	6.5	6.5	5.0
887	7.0	9.0	10.0
893	7.0	5.5	12.0

nine hills gave an increased yield over 1909, two remained stationary and three were lower. Turning now to the high yielding hills of 1909, shown in table 4, it appears that here the yield in 1910 was depressed in all cases but one where it remained stationary.

In 1911 seven hills gave an increased yield over 1909, and five were lower in yield. Considering now the data of the two tables together and making due allowance for the unfavorable season in 1910, certain apparent tendencies may be thus expressed: in the given population the yield of some individuals tends to decrease from year to year, that of certain others tends to increase and that of still others remains approximately constant. This is not a generalization on the part of the writer but merely a suggestion as to certain variations in behavior of the plants studied which are worthy of more extended observation. It may be that these tendencies are due to the varying sensibility of

the plants to changed conditions as pointed out by Shull and by Love, or to a certain periodicity in yield such as has been observed in apples and other fruits, or to differences in the length of the life cycle of various individuals, some having been observed in the ascending phase, others in the descending phase.

It is evident that the most desirable individuals for commercial purposes are those which are least subject to variation and which most nearly maintain a level of performance with respect to yield. The selection for propagation of an individual giving a high yield in one year does not insure that it or its progeny will be in the same class in succeeding years. It also appears unwarranted to assume on the evidence of one or two years that a low yielding individual will necessarily continue low yielding and transmit the same tendency to its progeny.

TABLE 4.—*Three year record of hills highest in yield in 1909.*

Hill number.	Yield in pounds.		
	1909.	1910.	1911.
184	12.0	5.0	10.5
271	14.0	5.5	13.0
344	12.0	4.5	5.0
400	12.5	7.0	14.5
456	14.5	8.5	14.0
493	12.0	9.5	12.5
499	13.0	8.5	14.5
513	18.0	15.0	15.0
582	14.0	9.5	15.0
794	12.0	6.0	16.5
884	13.0	11.0	16.5
938	11.5	11.5	13.5

The logical course, therefore, seems to be to study the individual plant through a series of seasons until some reasonable forecast can be made as to the degree and direction of its variations. It should then be possible to choose plants for propagation which will be far more stable and profitable than thousands that are under cultivation today.

The problem of selection is further complicated by the necessity of taking into consideration along with the variations in yield the numerous other variations mentioned in the beginning of this paper. The writer's observations, therefore, from which the data given above has been selected, are planned to cover at least five years, and as much longer as circumstances shall permit, for it is believed that only through such a study of individual performance can the answer be found to certain questions of practical importance to every grower of hops.

SOME OBSERVATIONS ON TOBACCO BREEDING

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Where it is desired to work with self-fertilized species the tobacco plant, on account of its habits of growth, the ease with which crossing is effected, the exceedingly large number of seed obtained from a single plant, etc., is particularly attractive for the experimental plant breeder. For the practical breeder, however, the case is quite different. The main purpose of the present paper is to call attention to some of the limitations of practical tobacco breeding, as well as to point out some of the serious difficulties met with in attempts to develop new or improved commercial types of tobacco, as gathered from observation extending over the last half dozen years. The writer is of the opinion that during the last decade the subject of practical plant breeding has been somewhat overdone, in the sense that there has been an undue concentration of effort on obtaining immediate results without adequate consideration of the underlying principles involved. As a consequence one might well question whether the results obtained are commensurate with the enormous amount of work which has been done. It hardly seems likely that there will be more than occasional cases of conspicuous success mingled with the flood of failures until we have more definite knowledge of fundamental principles on which to build systematic methods of practical breeding. At any rate, we can safely say that this condition of affairs holds good in the case of tobacco breeding.

RELATION OF ENVIRONMENT TO THE DEVELOPMENT OF THE TOBACCO PLANT

We would call attention particularly to the failure of many plant breeders, especially in dealing with the practical phases of the subject, to give proper consideration to the matter of environment. It is a simple matter to draw theoretical distinctions between fluctuations and inherited characters, but in practice the characters which it is sought to improve are in most cases those which are greatly influenced by environment. We need to know, first of all, therefore, something as to the relation of environment to plant growth, with respect to those characters concerned in the breeding problem. To expect to develop a thin cigar-wrapper type of tobacco on a heavy, clay soil is very much the same as expecting water to flow up hill by gravity.

FIG. 1. MARYLAND MAMMOTH TOBACCO.

Produced by crossing two types of Maryland tobacco. This type is the same as shown in fig. 2. When grown in small pots with reduced water supply abundance of seed are produced and the leaves are greatly reduced in number and size and are much narrower.

After having delimited the problem in breeding so as to bring it into reasonable harmony with the influences of environment, it is clear that in order to secure a reliable measure of the results obtained the environmental factors must be eliminated. The plant breeder is frequently content to compare the behavior of, say, a half-dozen individuals of several varieties, types, or strains, grown on the same plot of soil and during the same season, with respect to such characters or qualities as yield, height of plant, etc., whereas it is a perfectly well-established fact that it is very difficult, and often impossible, to secure even approximate uniformity in environment. We would emphasize the fact that in practice uniformity in environment cannot be attained, and hence the misleading effects of fluctuations can only be eliminated by dealing with sufficiently large numbers of individuals and by duplicating or repeating the tests. Figs. 1 and 2 are presented as illustrating the extent to which environment may modify habit of growth without breaking the type. The so-called Maryland Mammoth, shown here and referred to more fully in succeeding paragraphs, normally forms upwards of 100 leaves and continues to grow until frost without showing any indication of blooming. By growing in a small pot with reduced water supply the shape, size, and number of leaves are radically changed and the plants bloom freely, finally setting an abundance of perfectly developed seed.

In the case of practical tobacco breeding the environmental effects are of extraordinary importance for several reasons. The leaf constitutes the portion of the plant which is of commercial importance, and leaf development is, of course, greatly influenced by environment. Again, the commercial requirements are very different for the different classes and types of tobacco, and these differences have their origin for the most part in the varied soil and climatic conditions under which the several types are produced. Furthermore, quality, which, in the last analysis, is dependent on chemical composition, is usually paramount to yield, and environment here plays a subtle but dominating rôle. The characteristic properties or qualities of a given commercial type of tobacco are the combined product of heredity and environment, and of these two factors it must be conceded that environment is the more important. Connecticut Havana and Ohio Zimmer Spanish are two well-known commercial "varieties" which are used for very different purposes and, when grown in their respective native regions, are absolutely different in those characteristics on which depend the commercial value of cigar tobaccos. And yet, as Houser has pointed out, when these two varieties are grown side by side, it

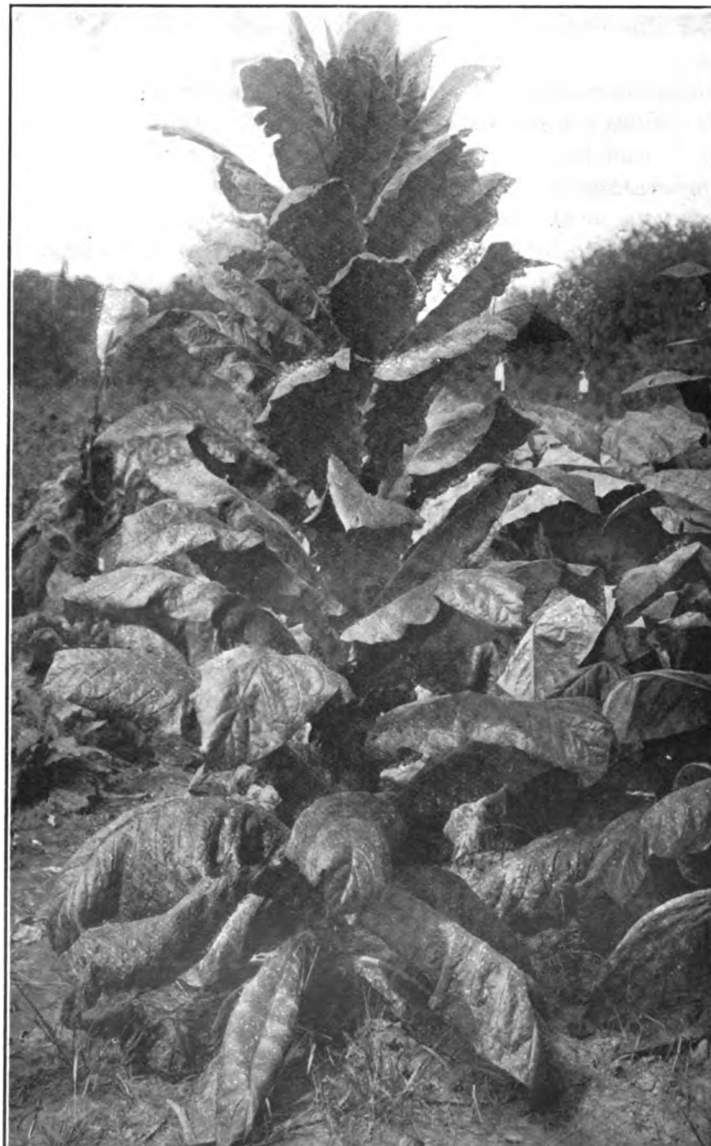

FIG. 2. MARYLAND MAMMOTH TOBACCO.

Produced by crossing two types of Maryland tobacco, illustrating effect of change in environment on habits of growth. This type is the same as shown in fig. 1. Under normal conditions it continues to grow till frost without blooming, forming upwards of 100 leaves.

is impossible to distinguish the one from the other! The tobacco breeder who overlooks these significant facts is likely to waste his efforts.

The best available evidence gathered from the experience of growers in the various tobacco districts, from the above mentioned viewpoint, seems to lead to the inevitable conclusion that there is no true line of demarcation between inherited characters and fluctuations with respect to many characters of commerical significance; in other words, there appears to be a progressive, cumulative effect of environment which represents a more or less gradual readjustment to changed environmental conditions. It must be said, however, that direct experimental evidence on the subject is wanting.

With respect to the breaking of type, that is, the production of mutations, by change of environment the evidence in the case of tobacco is far from satisfactory, mainly for the reason that where distinct strains have been isolated there is generally no certainty that the original stock was not mixed. We do not know of a case where distinct strains have been obtained from an authentic pure line as a result of change of environment. We have, however, one case where a Connecticut type which, although showing unmistakably the earmarks of a hybrid, is apparently uniform in habits of growth in its native region but which broke into several distinct forms when grown in Pennsylvania. The writer and assistants now have in progress a series of experiments with several pure strains from which it is hoped to secure more definite information regarding (1) the effect of environment on specific habits of growth and properties of the leaf, (2) the cumulative effects, if any, of environment, (3) the effect of environment on breaking the type. On the last-mentioned point it may be said that the evidence from the first year's work is purely negative.

OUR PRESENT KNOWLEDGE OF TOBACCO BREEDING

Inbreeding.—Tobacco is a typically close-fertilized plant and it is perhaps not surprising to find that continued inbreeding, so far as it has been pushed, has given no indication whatever of causing deterioration. A number of types have been inbred by growing the seed under bag for six to eight years without any observable change in vigor or habits of growth.

Continued selection.—It is undoubtedly true that tobacco is occasionally cross-fertilized and mixed types are frequently found in commercial crops. It is an extremely simple matter to select out the

more desirable forms with respect to productiveness and habits of growth and to isolate these by saving the seed under bag. At the present time, however, we have no evidence that, isolation of these homozygous forms having been once effected, any further improvement can be brought about by continued selection within these strains.

Hybridization.—East[a] has shown that the first generation of hybrids between different species of Nicotiana may or may not show increased vigor as compared with the parents and that the same holds true in the case of crosses between different varieties or strains of *tabacum*, the determining factor, of course, being the degree of heterozygosis, which may or may not be correlated with external or visible differences in form. We may say, therefore, that hybridization of our commercial types of tobacco usually, but *not always*, results in increase of vigor in the F_1 generation. It has been shown that the increase in vigor is expressed mainly in greater root development, longer internodes, and more rapid growth. It will be seen that these characters do not necessarily denote increase in productiveness, but there is abundant evidence that increased leaf development, that is, increased productiveness, is usually obtained, although it must be admitted that there is a dearth of reliable statistical data. Houser has pointed out the possibility of utilizing first-generation hybrids for the growing of tobacco commercially, and where increased productiveness is the primary aim it would seem that this method is practicable; but it is to be remembered that commercial requirements are vastly different for the various types of tobacco, and in many cases yield is secondary to quality. In such cases it must first be shown that there is uniformity of quality in the F_1 hybrids and that the quality is at least as good as that of the types now in use. It must be understood that uniformity in characters observable in the field by no means indicates uniformity in those characteristics on which commercial value depends.

Since whether or not there is actual heterozygosis, rather than external differences of form, determines the increase in vigor, it cannot be known in advance that any particular cross will show increased vigor. In other words, we cannot by mere inspection of the parent plants determine their relationship in this particular. Mr. E. K. Hibshman working in Pennsylvania found, for example, that two strains of the same type, apparently very closely related, the only known difference being that they had been grown on somewhat different soil types, gave, when crossed, a marked increase in vigor. In many cases the

[a] Bur. of Pl. Ind., Bulletin 244.

F_1 generation is intermediate between the parent types with respect to habits of growth, but this is not always true. The F_1 generation of a cross between Little Oronoco and White Burley was indistinguishable in all respects from the Oronoco parent, except that the plants showed very clearly increase in vigor. By crossing two types of Maryland tobacco Mr. D. E. Brown obtained the so-called Maryland Mammoth, possessing remarkable vegetative vigor and not closely resembling either parent. This type has remained fixed from the beginning and under ordinary field conditions continues to grow till frost without blooming, often producing as many as 150 leaves. The root stock, when transplanted under glass, sends out suckers which set seed readily and, as shown in fig. 2, the original plant can be made to bloom under certain conditions.

Experience has shown that the production of new, stable forms by hybridization in the vast majority of cases involves, at best, careful and long-continued selection. As a matter of fact, we are unable at the present time to point to a single instance in which hybridization and selection have produced a type definitely known to be fixed with respect to characters susceptible of measurement. Nevertheless, hybrids have been developed which show sufficient uniformity to warrant their commercial use where the requirements as to quality are not particularly exacting. If the tobacco breeder's problems were limited to the scope of those for most crop plants, namely, increase in yield and, perhaps, improvement in habits of growth, disease resistance, etc., the field would be far more promising, but the complications introduced by the question of quality of the cured leaf, which are discussed in succeeding paragraphs, make it very doubtful whether much can be accomplished in the betterment of the more highly specialized phases of the industry by hybridization and selection.

Breeding for nicotine content.—Nicotine is the characteristic alkaloid of tobacco to which is due primarily the physiological effects of the leaf but which has little to do with the flavor or aroma. The quantity of nicotine contained in tobacco can be readily determined, and since many individuals who use tobacco prefer it in very mild form the writer some years ago undertook the development of a type of cigar filler leaf low in nicotine content. It was early recognized that the production of nicotine in tobacco is greatly influenced by soil and climatic conditions and also by cultural methods, so that these factors must be rigidly controlled in dealing with the breeding phases of the problem. As a result of several years' work, we have obtained a type of Cuban tobacco of which the average nicotine content for the leaves

of 30 individuals grown in east Texas in 1910 was only 0.34 per cent, the highest figure for any individual being 0.50 per cent and the lowest 0.18 per cent. Cigars made from this type are the mildest of any we have ever tested. The nicotine content of our standard filler types usually runs from 2 to 5 per cent.

On account of the increasing demand for nicotine as an insecticide, it is not unlikely that tobacco could be profitably grown solely for obtaining this constituent, provided means can be devised for increasing the amount contained in the plant. We have recently undertaken experiments with a view to developing types characterized by high nicotine content, and this problem is perhaps simpler than that discussed in the preceding paragraph, for the reason that no attention need be paid to the quality of the leaf.

TOBACCO BREEDING FROM THE GROWER'S STANDPOINT

Attention has already been called to the fact that the tobacco breeder must consider the quality of the cured leaf, as well as the productiveness and other visible habits of growth, and quality is frequently paramount to productiveness so far as financial returns are concerned. Unfortunately, quality is often more or less antagonized by those factors tending toward increased productiveness, and this matter is of such vital importance that we have thought it desirable to bring out clearly the two distinct phases of practical tobacco breeding.

We have abundant evidence that such characters as shape, size, and number of leaves, extent of suckering, and length of internode can be largely controlled by well-directed efforts in hybridization and selection, and, although it is extremely difficult to obtain stable recombinations, this can frequently be sufficiently approximated with respect to some of the more important characters to make the new forms very desirable from the standpoint of the grower. An excellent illustration in point is the Halladay type, described by Shamel,[b] which is in many respects an ideal type, from the grower's point of view, for the production of cigar-wrapper leaf. In general habits of growth and productiveness it is far superior to either parent, possessing the desirable characters of both, is perfectly uniform in growth, so far as can be observed by simple inspection, and, as a whole, presents a handsomer appearance in the field than any other tobacco the writer has observed. The weak points of this type as regards quality are referred to under the next heading.

[b] A. B. A., vi, p. 273.

Some of the characters relating to habits of growth, more particularly shape, size, and venation of leaf, are of special interest to the manufacturer, while others, such as number of leaves, length of internode, extent of suckering habit, and root system are of importance only to the grower. These latter characters are of importance with reference to yield, pole-sweat in curing, labor required, and vigor of growth and protection against unfavorable weather conditions, respectively.

The plant breeder must keep clearly in mind that the commercial requirements, as well as the problems of interest to the grower alone, are quite different for the several classes of tobacco, and he must, first of all, acquaint himself thoroughly with the requirements for the particular class of tobacco with which he proposes to deal. This done, by making a wise selection of parent stocks and confining himself to only a very few characters for improvement, he may hope to secure new forms which are desirable from the grower's standpoint alone, or from the manufacturer's point of view, as well, with respect to characters observable in the field. But we shall see that in some cases, at least, this is merely beginning the problem.

TOBACCO BREEDING FROM THE MANUFACTURER'S STANDPOINT

The financial returns from a crop of tobacco necessarily depend much on the yield obtained, but, as a rule, quality is of even greater importance in this connection and by quality is meant that of the *cured leaf* and not that of the leaf as it matures in the field. Quality, as the term is used commercially, is composed of such elements as color, texture, elasticity, aroma, flavor, body or thickness of leaf, and capacity for burning freely. The grower is naturally interested in both yield and quality, while the manufacturer is concerned only with quality. Maximum yield is frequently incompatible with highest quality, so that the interests of the grower and the manufacturer are to some extent antagonistic, but in the end the grower must meet as far as practicable the demands of the manufacturer.

The plant breeder must of necessity keep in mind the requirements of the manufacturer as well as those of the grower, but unfortunately there is no means of judging in the field most of the important elements of quality, and herein lies a difficulty almost insuperable to the practical breeder. He is in the dark as to quality while making his selections for characters observable in the field, and where there are a considerable number of independent elements constituting quality it

is readily seen what slight probability there is of obtaining *by mere chance* the desired combination, even when a sufficiently large progeny is grown to make it likely that this combination is present. Moreover, the matter is further complicated by the fact that in certain cases the leaf cannot be matured and cured under normal conditions if seed of the individual is to be obtained.

There is no demand for novelties in the tobacco industry, so that any new type produced must resemble more or less closely in the important elements of quality the standard types of the particular class in question. So far as known to the writer, no one has thus far succeeded in producing by hybridization a new type acceptable to the trade as regards quality in those classes of tobacco, such as cigar-wrapper leaf, for example, for which commercial requirements are very exacting. We have mentioned the Halladay as a conspicuous example of a type developed by hybridization which is almost ideal from the grower's standpoint, since it is decidedly superior to the standard Connecticut types with respect to vigor, size, shape, and number of leaves produced. The fundamental objection to this type is that the cured leaf departs from the standard requirements in such elements of quality as color, texture, and elasticity. The variable qualities of cured tobacco, such as color, aroma, elasticity, etc., of course depend on differences in chemical composition, but these differences are, for the most part, of such complex and obscure nature that they cannot be determined by methods of analysis now available. It is interesting to note in this connection, however, that the Halladay tobacco is markedly low in starch content, with a corresponding increase in organic nitrogenous constituents, as compared with standard Connecticut types such as the Connecticut Havana.

It has been pointed out that, in general, environmental factors exert a controlling influence in the development of most of the important elements of quality. We may recall, for example, that the world's standard of excellence for cigar-filler leaf is produced only in a very small area in Cuba known as the Vuelta Abajo district, and growers throughout Cuba recognize the fact that environment is the controlling factor in producing this renowned tobacco, practically no attention being given to the matter of seed. If there be any truth in the conception of the cumulative effects of environment, it would seem possible that growing a new, fixed type, which is deficient in quality of cured leaf, such as the Halladay, for several generations in a particular environment would result in its acquiring, to some degree at least, the quality characteristic of the tobaccos produced in that region.

Connecticut Havana and Connecticut Broadleaf are often grown on the same soil, and while distinct differences in quality between the two types are always observable, they are sufficiently similar in essential points to warrant their being used for the same purposes.

We have seen that the opportunities for developing improved types by hybridization are limited in dealing with those classes of tobacco in which several elements of quality are of the first importance, because of the difficulties in the way of systematic selection with respect to these elements of quality. The situation is more encouraging, however, in the case of other classes of tobacco, in which the requirements as to quality are less exacting and in which, consequently, increased yield assumes greater importance. We may mention Ohio cigar-filler leaf types developed through hybridization by Prof. A. D. Selby and assistants, in coöperation with the Bureau of Plant Industry, as cases in which increased productiveness has been obtained without prejudice, it is believed, to trade requirements. Again, we have developed in Maryland new types of increased productiveness by crossing the native types with Connecticut Broadleaf and with White Burley. These new types are sufficiently uniform in habits of growth, and meet commercial requirements well enough, to warrant their acceptance by the trade, and they are now being grown on an extensive scale.

CERTAIN RESULTS IN OHIO TOBACCO BREEDING

TRUE HOUSER

Germantown, O.

It is the intention in this brief paper to cover but a few of the many phases of recent progress in the tobacco breeding work which has been carried on since 1903 by the Ohio Agricultural Experiment Station at the Southwestern Sub-Station located at Germantown, in the heart of the Miami Valley cigar filler district.

During this period of time over 300 hybrids have been made and from the careful breeding out of the older ones a number of apparently valuable new varieties have been obtained, some of which are just beginning to be extensively grown by the farmers of this district. Many other types of later development give promise of still greater excellence, but are not yet sufficiently fixed or have not been tested long enough to warrant distribution. Year by year the hybrid work

grows in interest; better yields are being produced and other desirable qualities are being attained in larger degree with each passing generation. In addition to the work of developing new fixed types by hybridization followed by selection, we are now investigating the possibilities of growing first generation hybrids upon a commercial scale, thus putting the increased vigor of growth which is so characteristic of them to practical use. Attention was called by the writer to this phase of the work in a paper read before this association at last year's meeting at Columbus Ohio. The remainder of this paper is devoted to a brief account of hybrid 81, and to a short discussion of two phases of breeding for special adaptation, viz: "Drouth resistance" and "Increased ability to make use of the less available forms of plant food.'

HYBRID 81

This hybrid was made in 1904 by cross fertilizing a plant of hybrid 54 with Zimmer Spanish pollen. Hybrid 54 is a cross of Cuban by Connecticut Seedleaf, therefore 81 is half blood Zimmer Spanish, one-fourth blood Cuban and one-fourth blood Connecticut Seedleaf. The accompanying diagram shows the yields and lines of descent of its various selections from the first to the sixth generation. The wide variation in yield of the two selections grown in the second generation is accounted for by the fact that one parent, hybrid 54, was itself a first generation hybrid between two radically different varieties and thus would not transmit the same combination of unit characters to all its offspring.

In the third generation the two better yielding selections were in very marked contrast in regard to general appearances and habit of growth, and the descendants of both have remained constant in these characters though varying widely in yield and smoking quality. The one type, designated in the diagram by the solid lines, is a low growing sort with numerous, very erect, smooth leaves placed very close together on the stalk. The other type, represented by broken lines, is an extremely tall variety with semi-erect rather distantly spaced leaves showing a tendency to fullness between veins which contrasts strongly with the smooth surface of the leaves of the low type. Another distinguishing trait of the tall type is a peculiar modification of the inflorescence in which the central bud never opens until after several of the lateral ones have bloomed.

Both types are comparatively free from suckers and remarkably resistant to wind storms, very rarely lodging even under the most trying circumstances. The better selections of both types have a

fine flavor and aroma; cigars made from them being pronounced, by most persons who have tested them, superior to those made from Zimmer Spanish. Both types go through the process of fermentation very well and no damage has yet been found where the tobacco was packed in good condition. The low type is now being grown by quite a number of farmers in this vicinity and at other points in the Miami Valley. The yields in 1910 ranged from about 900 to 1500 pounds of the wrapper and filler grades per acre; in all cases being higher than those of Zimmer Spanish grown under similar conditions, the gains over the latter variety ranging from 17 to 46 per cent. The results for 1911 are just coming in and so far as received the yields run from 1474 to 1858 pounds per acre not counting the trash, which if added would increase the above yields by about 10 per cent. The gains over Zimmer Spanish this year run from 22 to 44½ per cent. In this connection it may be well to state that under the conditions where the highest yields of Zimmer Spanish are obtained this hybrid not only makes greater gains in pounds per acre but actually makes larger percentage gains. The largest increase, 44.5 per cent so far determined for 1911 was made over the largest Zimmer Spanish yield yet reported by any of our coöperative growers.

The appearance of this tobacco when stripped is very similar to Zimmer Spanish and as before stated gives no trouble in the warehouse and makes cigars of superior quality. Nevertheless, there has been manifest more or less disposition on the part of tobacco buyers, when they know a farmer is growing this hybrid, to discriminate against it; no doubt partly through prejudice, but in some cases evidently in the hope of obtaining good tobacco at a reduced price by this means. These same dealers have repeatedly demonstrated their inability to distinguish this tobacco from Zimmer Spanish, and since they buy other varieties like Closeleaf Spanish which is no more similar to the true Zimmer Spanish than is this hybrid and which gives much more trouble in the warehouse and is not superior to the hybrid in any other way, we believe the time has come for the farmer to grow more productive varieties than Zimmer Spanish, or else demand a higher price for the latter variety. It is not at all likely however, that the trade will long be willing to pay more for Zimmer Spanish than for similar and equally good tobacco of other varieties. Indeed there is good evidence for believing that large quantities of tobacco of several other varieties, including much of that grown in Wisconsin, are known as Zimmer Spanish by the time they reach the cigar manufacturer.

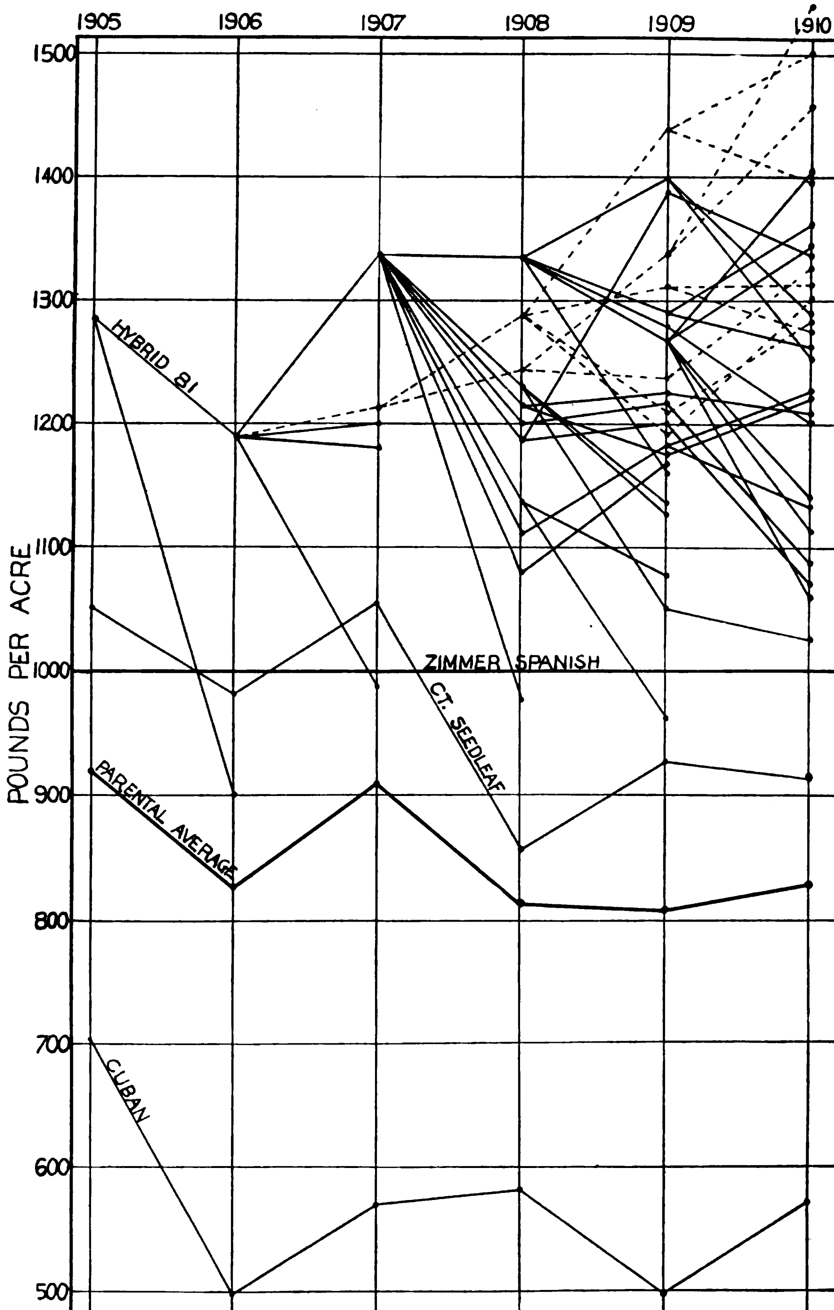

Fig. 1. Diagram Showing Yields of Hybrid 81 and its Three Parent Varieties.

The yields are corrected to the check plantings of Zimmer Spanish which is also one of the parent varieties.

A study of the diagram reveals a steady increase in yields culminating in 1910, the last year for which we have the data. The rather wide divergence in yield during the last two years found between selections tracing back to a common mother plant of the preceding season is no doubt to be accounted for in large part by differences in environment to which the various selections were subjected, for there is a marked difference in the adaptability of this hybrid and Zimmer Spanish to the different types of soil and different cultural methods employed at the Station farm. The irregularities in yield of the low type were more pronounced in 1910 as would naturally follow from the fact that these selections that year were not planted in duplicate but were scattered over the testing ground upon several types of soil and were partly on rotation ground and partly on ground under continuous culture of tobacco. Ordinarily when duplicate plantings are made if one planting occurs in an exceptionally poor place this is compensated for so far as possible by locating the other one in an exceptionally favorable situation. Of course there are always disturbing factors which can not be completely controlled, but we find much more consistent results where the different selections are grown side by side under nearly uniform soil conditions. It will be noted that the variation in yield from individual plants of common ancestry for the tall type, in 1910, which was planted in duplicate with the precautions above noted, is not very great.

This tall type still seems capable of improvement in the matter of yields, at least those of 1910 upon the average are considerably better than those of the previous year. However, this may be due simply to the greater drouth resistance of this type since 1910 was a very dry year. But if this be the true explanation there must certainly have been an improvement since 1908 which was a still drier season, in fact being the driest summer on record in the Miami Valley. Since 1909 was an extremely wet year it seems probable that the low type of this hybrid has about the same relative adaptability to wet and dry seasons as the Zimmer Spanish by which its yields each year have been measured. In this connection it should be stated that the yields given are not the actual yields but are calculated by adding the increase of the hybrid yields over the Zimmer Spanish checks, between which they grew, to 1000 pounds which is very nearly the average of all the checks for all the years covered by the diagram. Had the percentage gains instead of the increase in pounds per acre been used, the results would be somewhat modified and would no doubt give a truer expression of the yielding power of the various

selections, but the computation of these percentages would involve more time in going through old records to find the necessary data than is now at command of the writer.

Note also the yield of the other parents, Connecticut Seedleaf and Cuban, and the average yield of the three parent varieties and it will be seen that most of the hybrid selections have consistently maintained themselves much above the parental average, the best selection in 1910 yielding almost twice as much.

BREEDING FOR DROUTH RESISTANCE

More or less prolonged periods of hot, dry weather during summer and early autumn are of common occurrence in the Miami Valley, and the power of plants to withstand these conditions is an important attribute in determining their adaptability to this region, and should not be overlooked by plant breeders in their efforts to improve our cultivated crops.

The experiments from which the following data are collected were not planned with this end in view, but a fortunate combination of weather conditions occurring during the three years, 1908–1910, of which the first and last were very dry with an exceedingly wet season sandwiched in between, has presented a very favorable opportunity to study the relative adaptability of the hybrids and varieties, with which we were experimenting, to very excessive and to very deficient rainfall. The year 1908 in the Miami Valley was the driest within the memory of the oldest living inhabitants. At the Test Farm there was practically no rainfall during the whole period from the transplanting to the harvesting of the tobacco crop. The following year (1909) was one of the wettest years in the history of tobacco growing in this district; many fields of both tobacco and corn were abandoned to the weeds because the excessively wet weather made it impossible to cultivate them. 1910 was a very dry season but the drouth was less severe than in 1908.

It is not at all surprising that we should find rather remarkable differences in the relative adaptability to extremes of moisture existing among the different varieties of tobacco and other crops. In seeking to discover with what other characters the adaptability to extreme dry weather is correlated one of the first probable relationships that occurs to the mind is that heavy yielding varieties like Ohio and Pennsylvania Seedleaf would be less adapted to dry seasons than lower yielding varieties like Zimmer Spanish and Cuban, for we would

naturally expect it to take a great deal more water to produce a ton of tobacco per acre than but half this amount. When we compare a variety like Pennsylvania Seedleaf with Zimmer Spanish we find that this relationship holds true (fig. 2). The Seedleaf produces not only larger gains in pounds per acre, but a much larger percentage increase which is really a much better index than the gains in pounds per acre; again when we compare Cuban, which is a still smaller yielding variety than Zimmer Spanish, with the latter we find that the hypothesis still holds, the Cuban producing relatively more in the dry season.

But now let us turn to hybrid 75 (fig. 2). Here we find a variety, yielding much more than Zimmer Spanish, behaving in a very contradictory manner from what our hypothesis would lead us to expect in its relative adaptability to various amounts of rainfall. It will be noted from the diagram that the extremely wet year (1909) seemed to have depressed the yields of this sort in just about the same proportion that it augmented those of Pennsylvania Seedleaf. It is true that this hybrid has yielded somewhat less upon an average than the Pennsylvania Seedleaf but if we take its best selection which has the adaptation to dry weather in accentuated form, we find but little difference in yield.

Four strains of this hybrid are represented in the diagram. The word strain as here used includes all the descendants of a single mother plant of the third generation (1906). In some of these lines of descent there has been much variation and a wide range in yields, as indicated on the diagram by the dotted lines which show the yields of the best selections in two of the strains, 75-A and 75-241. In the latter case it will be noted that there has been no improvement in yield since 1908. The yield of the best selection in both the dry years is considerably higher than the average for this strain, while in the wet year it is somewhat beneath the average. It is noteworthy that the average yields of all the selections in each of the four strains made larger percentage gains over Zimmer Spanish in 1908 than in 1910 when the drouth was less severe. 75-A shows a case of improvement, in 1908 this strain was represented by a single plant while in 1909 and 1910 quite a number of selections were grown. It is worthy of note that the best selection of this strain during both the dry years yielded more than its two parent varieties combined. This strain although in the seventh generation (1910) is still far from a fixed type.

All the strains shown in the diagram have descended from a single mother plant of the second generation (1905) and though differing widely in a number of particulars, all have retained the very dark

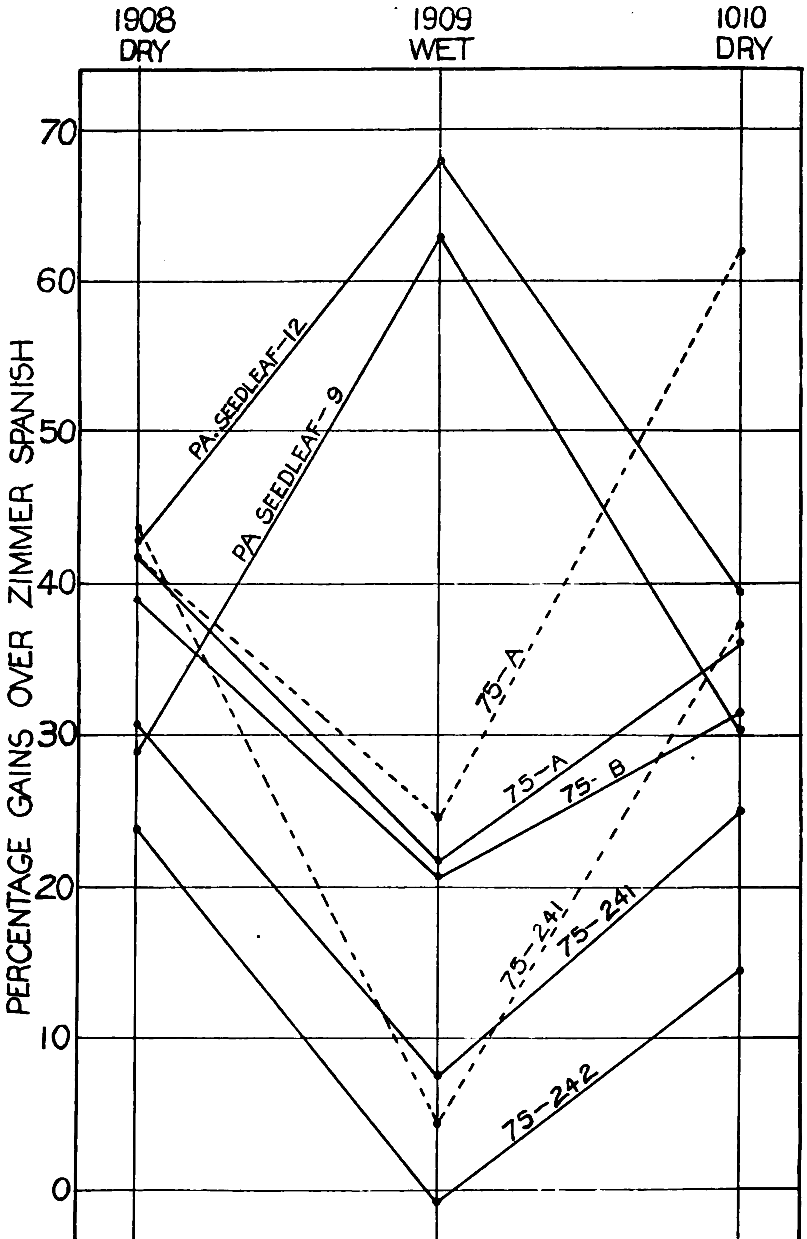

FIG. 2. DIAGRAM SHOWING MODIFICATION IN THE RELATIVE YIELDS OF FOUR SELECTIONS OF HYBRID 75 AND TWO SELECTIONS OF PENNSYLVANIA SEEDLEAF CAUSED BY SEASONAL VARIATIONS IN RAINFALL.

green color and very slow growth of the seedling plants so characteristic of the original mother plant. Without recourse to glass covered beds, it is very difficult to get plants in proper season for transplanting. The plants are very hardy and bear transplanting well but make slow growth until about mid-season after which their development is very rapid. Apparently they devote the greater part of their energy during the earlier part of the season to becoming well rooted which perhaps accounts for their ability to make such rapid growth later on even with very deficient rainfall. That they root much more extensively and deeply than Zimmer Spanish becomes quite apparent when one attempts to pull up the plants. It is quite easy to up-root even a large plant of Zimmer Spanish, but the same operation with a plant of this hybrid requires several times as much force.

Having in mind the distinguishing traits of this hybrid which is so remarkably adapted to deficient rainfall, can we safely assume that any or all of these characters are necessarily correlated with its power to withstand drouth? Up until 1910 we had no evidence that would negate such a contention, but in that year there appeared a strain of hybrid 127 (which by the way, is a cross between hybrid 75 and hybrid 80, an Ohio Seedleaf-Cuban cross) which possesses all the drouth resistance so characteristic of its paternal ancestor and has the same deep-rooting habit. But here the resemblance stops for this strain without exception among all the tobaccos known to the writer is the most prompt to germinate its seed and produce plants, which when transplated in the field start to grow with a rapidity which is astonishing. The appearance of the leaves is entirely different from hybrid 75 in color, form and texture. Having stated the remarkable ability of this sort to withstand dry weather in which it so much resembles hybrid 75, what of its behavior under opposite conditions` Here there is no resemblance at all for it makes the same remarkably luxuriant growth as in dry seasons, far outstripping Zimmer Spanish which is one of the most rapid growing varieties known. This type has not been grown in a season abnormally wet from beginning to end, but in 1911 when the conditions immediately after planting were quite moist it made at least twice as much growth as Zimmer Spanish during the first three weeks. Again toward the end of the growing season there occurred a very rainy period which seemed to have no deterimental influence upon the growth of this hybrid either absolutely or relatively.

This variety seems to have inherited from the Ohio Seedleaf, through its maternal ancestor, its remarkable adaptation to wet weather;

at the same time it seems to have inherited in a very remarkable degree the ability to withstand opposite conditions from its paternal ancestor, hybrid 75. Therefore it would seem that there is nothing antagonistic or mutually exclusive in the inheritable units whatever they may be which adapt tobacco to either of the extremes of rainfall. As to whether there may be a possible correlation between the peculiarities noted in the case of hybrid 75 and its lack of adaptation to an excess supply of moisture can not at present be determined for no other varieties or hybrids are known to possess the same peculiarities. This problem however can probably be solved by the study of crosses to be made between hybrid 75 and types like Pennsylvania Seedleaf.

BREEDING FOR INCREASED ABILITY TO UTILIZE THE LESS AVAILABLE FORMS OF PLANT FOOD

The tobacco at the Station is grown under two crop systems; one a three year rotation of tobacco, wheat and clover, the other continuous culture of tobacco. In the rotation where the tobacco follows clover, barnyard manure is applied to the clover sod thus furnishing a large amount of food in less available form than that applied to the continuous ground which is furnished largely in the form of commercial fertilizer. Tobacco in general is known to possess very meager ability, as compared with corn, to make use of the less available forms of plant food. This is in part due to the short growing season of the crop and we would naturally expect to find the later varieties to have more ability in this direction than the earlier ones, and in general this is true. Zimmer Spanish, an early variety and the dominant sort of this region, is remarkable for its inability to make the best use of barn-yard manure and like forms of plant food. In hybrid 54, a late sort, we have a tobacco which, in comparison with Zimmer Spanish, is very well adapted for such work (fig. 3). On the diagram are shown the average results from three selections of this hybrid which were planted each year on both continuous and rotation ground. It will be noted that this hybrid when grown in rotation made a very large increase over the Zimmer Spanish, upon the average amounting to nearly 40 per cent, while the corresponding gain for continuous culture is only about 16 per cent. It is noteworthy that the extremes in rainfall already noted for the years 1908–1910 seem to have been without effect upon the relative adaptability to these two systems of culture. The same diagram also shows the yields of hybrid 157, in which the opposite relationship to rotative versus continuous culture holds.

This is not yet a fixed hybrid and a great lack of uniformity was manifest in the plants especially in 1908 and 1909, but the character we are now studying seems to have been constant and while a very large increase in yield for both the rotation and the continuous culture was

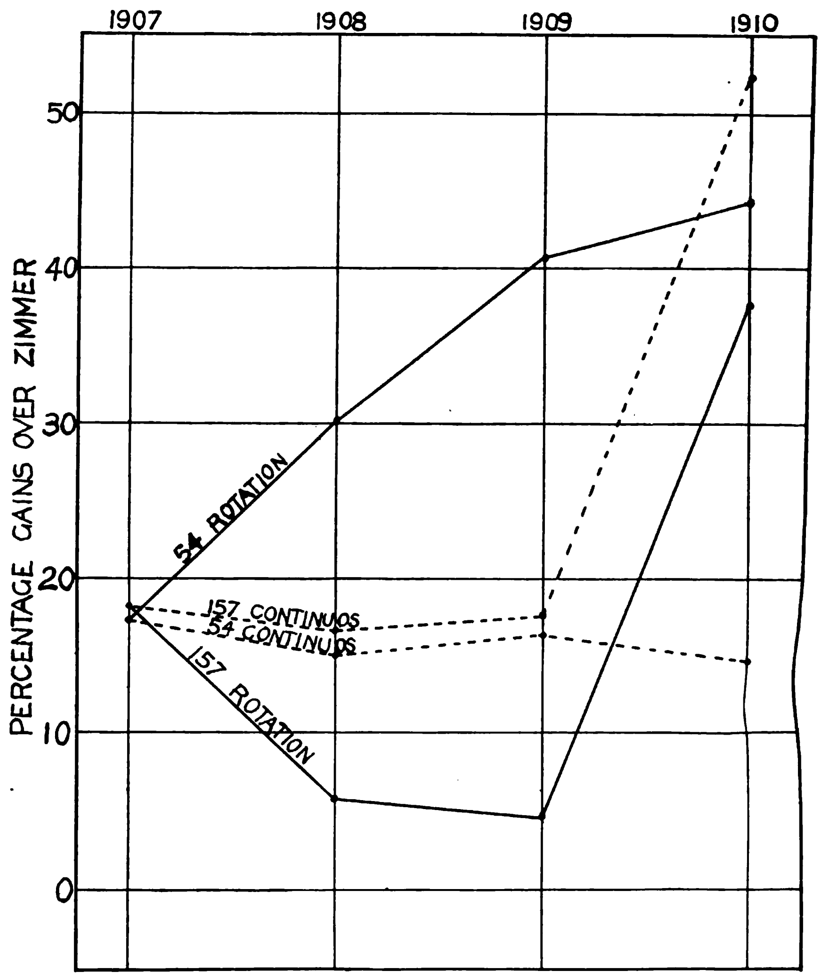

FIG. 3. DIAGRAM SHOWING YIELDS OF HYBRIDS 54 and 157 AS MODIFIED BY ROTATIVE AND CONTINUOUS CULTURE.

obtained in 1910, they still maintained approximately the same ratio to each other.

Hybrid 157 in date of maturity is intermediate between Zimmer Spanish and hybrid 54. Hence if the length of the growing season

was the only determining factor of the relative adaptability to the utilization of the less available forms of plant food, this variety should also be intermediate in such adaptability, but as a matter of fact we find it the least adapted of the three varieties. In this respect it differs from most of our hybrids for nearly all of them do relatively better when grown in rotation with other crops.

From the selection made in 1909 we seem to have developed in hybrid 157 a very high yielding variety which is even better adapted to continuous culture than Zimmer Spanish which among the older varieties stands preëminent in this respect. In appearance the tobacco closely resembles Zimmer Spanish and if the quality proves good should be a valuable sort for the grower having but a few acres of ground, the greater part of which he feels must be planted in tobacco every year.

APPLE BREEDING IN CANADA

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Apple breeding in Canada has not had a very long history, nor have there been many men engaged in it, but there have been a few enthusiastic workers who have done something in that country towards the improvement of the apple. The late Charles Arnold, of Paris, Ont., was probably the first man in Canada to breed apples by crossing. In 1873 he exhibited at the meeting of the American Pomological Society at Boston, Mass., eighteen varieties of cross-bred apples, all of which were seedlings of the Northern Spy crossed with Wagener. The only one of these which has become a commercial apple is the Ontario, well known in the province after which it was named. This apple has the size of the Northern Spy and the early bearing qualities of the Wagener. It is oblate, like Wagener, but resembles Northern Spy very much in color, though it has more bloom. The quality is good, but the flesh is somewhat tender for long-distance shipment. It is a winter apple. The Ontario apple received a special prize in 1874 from the Ontario Fruit Growers' Association.

One of the early workers in apple breeding in Canada was the late Francis Peabody Sharp, of Upper Woodstock, N. B.—born in 1823; died 1903. He began cross-breeding about the year 1869 and is said to have made a thousand crosses with the object of producing an apple which should have extreme hardiness and productiveness. He used to a large extent the so-called "New Brunswicker" apple for

the mother and the Fameuse for the male parent. An apple resulting from the crossing with the above parents which has obtained more than local prominence is the Crimson Beauty, at first called Early Scarlet, a handsome summer variety of medium quality which is being grown to a considerable extent in New Brunswick and other provinces in Canada. This apple began to be propagated in a large way in New Brunswick in 1887. Unfortunately Mr. Sharp did not leave a record of the parentage of many of his crosses. Some of the most promising of his crosses which have come under our observation are the following "Bittersweet," an autumn apple of good quality and said to be one of Mr. Sharp's earliest crosses between New Brunswicker and St. Lawrence. "Munro Sweet" (Sharp's), a sweet apple of good quality, with a season from early to mid-winter; said to be a cross made between New Brunswicker and an unknown apple about 1869 and fruiting first in 1879. "Woodstock Bloom," a winter apple, is another cross between "New Brunswicker" and Alexander, which has proved hardy in New Brunswick. The "New Brunswick" apple which so closely resembles the Oldenburg that most pomologists have not been able to distinguish one from another, is said to have originated with Mr. Sharp, and as this apple—whether it be Oldenburg or whether it be another variety—has been of very great value to New Brunswick on account of its hardiness and productiveness, the history of it given by Mr. Sharp and the Sharp family should be recorded in a paper on Apple Breeding in Canada. The apple is said to have originated in 1851. Mr. Francis Peabody Sharp obtained seeds from a nurseryman in Bangor, Maine, named Dunning. These were planted in his nursery at Woodstock. Some of the seedlings stood until the third year. In that year a Darius Shaw, who was working for Mr. Sharp, saw a vigorous looking tree in the nursery with several fine apples on it and brought Mr. Sharp's attention to it. This is the tree which was afterwards called the New Brunswicker.

The late Peter C. Dempsey, Albury, Ont., did considerable plant breeding and used the apple to some extent in his work. The only varieties used as parents of which we have been able to find a record are the Golden Russet and Northern Spy. He crossed these, and among the seedlings he obtained from this work two were named and are being grown today. These are the Trenton, a red September apple which is highly regarded near where it originated, and the Walter apple, a large, striped, October apple of good quality, not unlike Gravenstein in appearance, flesh and flavor.

Dr. Wm. Saunders, late Director of the Dominion Experimental

Farms, began the cross-breeding of apples in 1894, with the main purpose of originating varieties which would prove hardy in the prairie provinces of Canada.

In Bulletin No. 68, Progress in the Breeding of Hardy Apples for the Canadian Northwest, of the Dominion Experimental Farm Series, published in 1911, Mr. Saunders, before his retirement from the government service, gives a history of his work in breeding apples and the results which were obtained.

In his first crosses Dr. Saunders used as the female parent the *Pyrus baccata*, or Berried Crab. The tree on which most of the crosses were made was grown from seed obtained from the Imperial Botanic Gardens, St. Petersburg, Russia, in 1887. From the same lot of seed, trees had been sent to the Experimental Farm at Brandon, Man., and Indian Head, Sask., and as they had proved hardy there and produced fruit it was thought that this crab would be good material out of which might be developed hardy apples of marketable size for the prairie provinces of Canada, as up to that time, and even up to the present time, except in southern Manitoba, the successful culture of apples is very uncertain there; although we believe that in the wooded districts in Manitoba, Saskatchewan, and Alberta, where the soil is light and well drained, with proper methods of culture the hardiest apples of good marketable size could be grown successfully. The development of Dr. Saunders' work in cross-breeding has been well described by him in his bulletin, as follows:

After four or five years' experience had thoroughly established the character of the berried crab for extreme hardiness, efforts were made to improve the size and quality of the fruit by cross-fertilizing the flowers of *Pyrus baccata* with pollen from many of the hardiest and best sorts of apples grown in Ontario. This work was begun in 1894, and has since been continued along several different lines. The seeds obtained from the first crosses were sown in the autumn of that year and germinated in the following spring, producing, in all, about 160 young trees. These were planted in the spring of 1896, when many grew rapidly and soon made shapely specimens. These, and other young trees, resulting from similar subsequent experiments, have been planted from year to year in orchards at Ottawa, Brandon, Indian Head, and other northwestern stations. In 1899, thirty-six of the cross-bred apples first produced and grown at Ottawa fruited, and five of them were of such size and quality as to justify their being propagated for more general test. The fact that so many of these fruited in the fourth year from the sowing of the seed indicates a very early fruit-bearing habit. Since then several hundred more of these cross-bred apples have borne fruit, and the number of varieties worthy of extended cultivation has been considerably increased. Root-grafts of some of the more promising sorts were early made and these have been tested for eight or ten

years past at each of the northwestern farms and have shown very slight inclination towards tenderness, even when planted in exposed situations. The cross-bred sorts grafted on roots of seedlings of *Pyrus baccata* have produced trees which, so far as they have been tried, seem to be quite as hardy as the wild form of *baccata*. There seems every reason to expect that they will prove generally hardy throughout the northwestern country.

Experiments with Pyrus prunifolia and Pyrus malus.—In 1896 a series of crosses was begun on another sort of wild crab, known as *Pyrus prunifolia*. This is regarded by some botanists as a distinct species; others believe it to be a hybrid between *P. malus*, the wild crab of Europe, and *P. baccata*. Seeds of this form were also obtained from the Royal Botanic Gardens, St. Petersburg, Russia. The fruit of *P. prunifolia* is usually larger than that of *baccata*, and will average nearly twice the size. Its hardiness in the Northwest has also been established by a test covering a number of years on both of the experimental farms at Brandon and Indian Head. The first crosses with this species were made in 1896, and since then many new sorts have thus been originated.

Another line of work in producing new apples was begun in 1902, in crossing *Pyrus malus*, the wild apple of Europe, with some of the best Canadian sorts. This fruit is about an inch in diameter to start with, and of fair quality. A hardy form of this tree has been secured which has stood several winters at Brandon and Indian Head without injury, and with this additional crosses have been made.

Many of the best of the crosses produced on *P. baccata* and *P. prunifolia* have been recrossed, thus introducing a second quota of the blood of the larger apple with the hope of obtaining fruits of larger size and better quality. Regarding these there is as yet not much proof that they are sufficiently hardy to endure the climate of the Northwest; this can only be fully determined by further experiment. Two varieties of these crosses of Ontario and Spy have been tested for several years at Indian Head, but have not yet fruited. Thus far they have been fairly hardy. The first one-year-old trees produced by this method were planted in the orchard at Ottawa in the spring of 1904 . . . .

Apples from which pollen has been used.—In the first crosses made on *Pyrus baccata*, in 1894, pollen was used from the Tetofsky, Duchess, and Wealthy apples, but since then pollen has been obtained from many other varieties and used on *P. baccata*, *P. prunifolia*, and *P. malus*, among them Anis, Beautiful Arcade, Broad Green, Excelsior, Fameuse, American Golden Russet, Haas, Herren, Krimskoe, McIntosh Red, McMahan White, Osimoe, Pewaukee, Red Astrachan, Ribston Pippin, Scott's Winter, Simbirsk No. 9, Swayzie Pomme Grise, Tolman Sweet, Winter St. Lawrence, and Yellow Transparent. The number and variety of the crosses have thus been very much increased. Many hundreds of these cross-bred varieties of *baccata* origin have been produced, and most of them have fruited. While a large number have proved of inferior quality, there have been originated, up to the present time, about sixteen varieties in all, most of which, from their superior size and quality, may be regarded as useful for domestic purposes and deserving more extended trial.

The best varieties resulting from these crosses were named and are described in Bulletin No. 68. The names are Alberta, Bow, Charles, Columbia, Elsa, Jewel, Kent, Mecca, Norman, Osman, Otto, Pioneer,

Prince, Robin, Romney, Silvia, Tony. These are the best out of about 800 trees.

The fruit of the *Pyrus baccata* used by Dr. Saunders as the female parent is about a half to three-quarters of an inch in diameter. The larger of the first generation of crosses are from one and one-quarter to one and three-quarters of an inch in diameter. The better ones have little or no astringency and compare very favorably in quality with the best named crab apples on the market. Nearly all of them retain the marked crab characteristics of long, slender stem; thin, tender skin; and crisp, breaking flesh. Some of them have proved distinctly hardier than others when tested in the prairie provinces. Some of the hardiest are Columbia, Osman, Jewel and Silvia, and it is interesting to note that the female parents in all these cases were hardy Russian varieties.

It will be noted that in these first crosses no reference is made by Dr. Saunders to any reciprocal crosses with *Pyrus baccata* as the male parent. We understand that few crosses were made with the crab as the male parent.

The best of these crosses were sent to about 200 locations in the Canadian Northwest representing altitudes ranging in elevation from 740 to 4200 feet. The first distribution was made in 1902. Dr. Saunders reports in his bulletin, "Reports have come in from many who received the trees, and in almost every instance they are reported as entirely hardy, having stood the winters to which they have been exposed without injury, and in some instances borne fruit." The furthest north that these crosses have fruited so far as we are aware is at Fort Vermilion, Peace River, in latitude 58°, the first fruit recorded being in 1910.

Many hundred seedlings of these first generation crosses have been raised, with the expectation that some of the seedlings would be even larger than the parent, but in practically every case the seedlings were smaller and many reverted to the size of *Pyrus baccata*.

In order to, if possible, obtain larger apples and still retain sufficient hardiness in the crosses to withstand the severe climate of the prairies, Dr. Saunders re-crossed the best of the first-generation crosses with some of the cultivated varieties of the apple. From these second crosses, which were made in 1904 and following years, there were this year 407 trees growing in the orchard at Ottawa. A number of these have now fruited, and while the majority bear little, if any, larger fruit than the female parent a few are considerably larger. Martin, which is a cross between Pioneer and Ontario, is 1⅞ inches by 2¼

inches in size, and there are others not named which are about as large. Most of these crosses still retain the long, slender stems, the thin, tender skin, and the crisp, breaking flesh which are characteristic of this crab apple. The fruiting of the remainder of these crosses and the testing of the best of them in the colder parts of Canada to determine their hardiness is awaited with much interest. A few crosses were also made by Dr. Saunders between the named varieties of apples and between the Hyslop crab and the apple. Three apples resulting from this work which have been named are Rideau (Wealthy × Oldenburg), Fairfield (Hyslop × Oldenburg), Samson (Oldenburg × Anis), which will be useful if they prove hardy in the prairie provinces. Dr. Saunders was assisted in his work by his son, Dr. Charles E. Saunders, who made a large number of the crosses.

In the year 1895 Mr. John Craig, then horticulturist of the Central Experimental Farm, Ottawa, did some crossing with the object of obtaining hardy, long-keeping apples, of which there is a great need in the colder parts of Ontario and Quebec. He crossed McMahan with Scott Winter, and Walbridge with Northern Spy. Of the former cross there were 37 trees, and of the latter 7 trees. A number of winter apples resulted from this first cross. Neither of the parents is of good quality and the crosses are lacking in this respect also, but as the trees appear very hardy and the apples are attractive in appearance some of them have been named. Four of the most promising are Granby, Walton, Sorel and Kelso. None of the crosses between Walbridge and Northern Spy have been considered good enough to name. The flesh of most them has been very firm. Work in raising apples from seed from naturally pollinized flowers was begun by Mr. Craig in 1890, when 3000 seedling apples trees were planted out at Ottawa. These were raised from seed imported from north of Riga, in Russia. The trees began fruiting in 1897. Most of the trees proved very hardy, but while the fruit of a large proportion of them was as good as many of the named Russian apples which were introduced into Canada, very few of them were considered superior. Rupert, Percival, Neville, Oscar, and Claire are five of the best of these.

In 1898 the writer, believing that in an orchard at the Central Experimental Farm, Ottawa, containing between 400 and 500 named varieties of apples all sorts of combinations of characters would be taking place by natural pollinization and that the chances of obtaining some good seedlings by sowing seeds from some of these varieties would be very great, had seed saved of some of the best-flavored apples then fruiting in the orchard, as well as some other varieties

desirable on account of other characteristics. There were included in these the McIntosh, St. Lawrence, Fameuse, Wealthy, Shiawassee, Swayzie, Scott Winter, Salome, Lawver, Gano, Northern Spy, Winter St. Lawrence, and Bullock (American Golden Russet). The seedlings of these and others which were sown later have been planted out at different times, beginning in 1901, until about 2000 trees were planted, this being all we had room for. The first tree to fruit from seed was a Wealthy seedling now called Crusoe, which fruited in 1903, two years after planting and five years from seed, and it may here be stated that the great majority of the Wealthy seedlings were early bearers like the female parent.

The good results which it was hoped to obtain by planting seedlings from fruit from trees which must have received pollen from a great many varieties has been abundantly borne out by the actual results. During the past eight years 997, or practically 1000, of these seedling varieties have fruited. Of 581 of these of which detailed descriptions had been made previous to this year, 78½ per cent were of marketable size, and only 5 per cent were small or crab-like. Of the 997 varieties, over 200 have been considered so promising that they are being propagated for further test and between 50 and 60 of the best have been named.

Some most interesting facts have been noted in regard to the way in which the seedlings resemble the female parent. If the parent is bright in color most of the seedlings are bright in color, but if dull in color then the seedlings are dull in color. If the parent is an apple of good quality then with few exceptions the seedlings are above medium to good in quality, and on the other hand if the parent is of inferior quality the seedlings are of medium quality also. If the parent is a long keeping apple then most of the seedlings are good keepers. Size has not been as constant as some other characteristics. Where there is a marked difference in size between the majority of the seedlings and the female parent it is in the direction of larger fruit in the seedlings. For instance, the fruit of the seedlings of American Golden Russet, Swayzie, and Fameuse average larger than the parent. Where seed has been examined carefully it has been noted that as far as size of seed is concerned the seed of the majority of the seedlings resembles the female parent. The varieties which gave seedlings which had the most characteristics of the female parent are Wealthy, Gano, McIntosh, and Langford Beauty. Those least resembling the female parent are Swayzie and Fameuse. The seedlings of Fameuse have been the most disappointing of all, there being a large proportion of varieties of inferior quality. The largest proportion of promising

seedlings are among McIntosh, Langford Beauty, Northern Spy, and Wealthy. Of the fifty-odd varieties which have been named the following are the most promising:

McIntosh seedlings: Lobo, Melba, Carno, Nemo, Joyce and Brock.

Langford Beauty seedlings: Kim, Ripon, Horace, Kildare, Gerald, Cora, Sonora.

Northern Spy seedlings: Rocket, Thurso, Rosalie, Clinton, Glenton, Bingo, Parma, Cecil, Nestor and Niobe.

Wealthy seedlings: Mendel, Luke, Galetta, Pinto, Medford, Battle, Melvin, Crusoe.

Lawver seedlings: Cobalt, Danville.

Shiawassee seedlings: Petrel.

Salome seedlings: Nepean, Rouleau.

Scott Winter seedlings: Bruno.

Fameuse seedlings: Herald.

Gano seedlings: Roger.

Swayzie seedlings: Ottawa, Radnor.

Winter St. Lawrence seedlings: Linton, Atlas, Nile, Albert, Anson.

As there are very few winter apples hardy enough for the colder parts of Canada where the apple is grown successfully, these new varieties, of which about half are winter apples, should prove of great value, and they are being propagated with a view to a more extended test of them. As this kind of apple breeding had given such good results, seed was saved in 1908 of some more of the best hardy winter apples grown at Ottawa, including Milwaukee, Bethel, Winter Rose Baxter, LaVictoire, and Stone from which we have about 1500 trees, part of which have been already planted in the orchard.

As it is important to obtain apples suitable for the prairie provinces of Canada as soon as possible, another method than that followed by Dr. Saunders is being practiced by the writer. Seed was sown in 1910 of some of the hardiest Russian apples, including Transparent, Charlamoff, Beautiful Arcad, Oldenburg, Tetofsky, Anis, Antonovka, and Hibernal. From these, over 17,000 seedlings have been raised and next spring these will be sent to the Dominion Experimental Farms in the Canadian Northwest and planted close together in nursery rows. After three years any which prove hardy up to that time will be removed to an orchard for further test. A much larger quantity of seed of other hardy varieties was sown in the autumn of 1911, and it is planned to continue this work from year to year in the hope that from some of these hardy Russians which stand so much cold in Russia will be obtained some which will be useful in the cold districts of Canada, where early growth in the spring followed by frost seems as destructive as low temperatures of winter.

Cross-breeding apples in the horticultural division.—Although considerable attention has been paid to the raising of naturally pollinized seedling apples by the writer, cross-breeding has not been neglected. The work of cross-breeding apples was begun by the writer in 1899 and has been continued from time to time since, although the opportunities for this work have been so limited that comparatively little crossing could be done in any one year. In 1900 I was assisted in this work by Mr. D. T. Elderkin, and in the year 1909 and 1910 by Mr. J. F. Watson. There are now between 800 and 900 different cross-bred trees growing as the result of this work. In order to make the chances of obtaining desirable apples greater, quite a number of varieties have been used as parents, in most cases reciprocal crosses with the same varieties having been made, thus making many more combinations than the number of varieties might indicate. The varieties used as parents have been Anis, Anisim, Antonovka, Baxter, Bethel, Oldenburg, Dyer, Fameuse, Forest, Hibernal, Lawver, Lowland Raspberry, Malinda, Milwaukee, McIntosh, McMahan, Newton, Northern Spy, Northwestern Greening, Scott Winter, Stone, Winter Rose, and Walton.

But few of the cross-bred trees have yet fruited, but those that have indicate that desirable characters of both parents can be obtained in the crosses. For instance, crosses between the Lawver and McIntosh, the former a very long-keeping apple, have resulted in some varieties that are better keepers than the McIntosh and better in quality than Lawver. In this particular cross, however, the character of "lack of hardiness" in Lawver was not known when the crosses were made. For which reason, doubtless, a large proportion of the seedlings show lack of hardiness and vigor.

It is intended to continue apple breeding in Canada, both from naturally pollinized flowers and from artificially pollinized flowers, and it will be our endeavor while obtaining results of immediate practical value to keep such records as may help to assist plant breeders in arriving at surer methods of obtaining the results desired.

Experiments in breeding apples by bud-variation are also in progress. During the past 14 seasons records have been kept of the yields from individual trees in the orchards at the Central Experimental Farm, Ottawa, and marked differences in yield have been recorded. Trees of the Wealthy apple propagated from heavy, light, and annual bearing trees are being grown to find if this habit is continued. These trees are now beginning to bear, and we look for some interesting results soon. We have also the different strains top-grafted on the same tree.

SYSTEMATIC BOTANY OF THE PLUM AS RELATED TO THE BREEDING OF NEW VARIETIES

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The first varieties of plums grown by white men in America were either imported from Europe or were grown from seeds of Old World varieties obtained by enterprising colonists and experimenters. So long as the development of the country did not take the fruit industry beyond the region in which these varieties could be grown with fair success there was little occasion to direct attention to the native species. These European varieties, however, so far as the country east of the Rocky Mountains is concerned, are not extensively grown south of New York or west of Michigan, and for the remainder of this territory it is necessary to depend upon those originating from the native species, or from species possessing like qualities of hardiness, or upon varieties of hybrid origin, if plum culture is to meet with success. The utilization of the material available has been greatly retarded through lack of knowledge of the botanical characters of the species and through improper classification of many of the horticultural varieties as they were introduced. This misconception of the species and of their relationships is even yet frequently much in evidence. The classification of varieties made by horticulturists is usually based mainly on those characters which vary most even within the species, such as the form, size, and color of the fleshy parts. The more fixed characters are generally those for the sake of which the species are not cultivated. Another source of error on the part of horticulturists is the restriction of study largely to cultivated material. Cultivated varieties owe their introduction to some excellence or to some character in which they are supposed to be an improvement over the usual form of the species, and the study of only such material necessarily leads to a misconception of the real character and relationships of the species to which these varieties belong. There has been a tendency too on the part of some botanists to establish species on the basis of differences found from the study of a small amount of material obtained from more or less isolated localities in the real range of a given species; an unsatisfactory and unreliable method so far as woody plants are concerned. The only work that has contributed in a marked degree

to a correct knowledge of the species is that by Prof. L. H. Bailey,[a] *The Cultivated Plums and Cherries,* published in 1892. Probably no other single event so stimulated and influenced the direction of plum culture in America.

After studying nearly all of the species in the field, more than four hundred cultivated varieties in the orchards and experiment stations of twelve states as well as in the herbarium, and four thousand or more specimens from wild trees, it has been possible to recognize twenty species and a few forms of lesser rank. Five of these species have been utilized in horticulture to a considerable extent, and probably not less than seven others possess sufficient merit to be worthy of the attention of the breeder. These twelve species are naturally separable into six groups.

Native species of prunus worthy of development.

AMERICANA GROUP	*nigra* *americana* *mexicana*
SUBCORDATA GROUP	*sobcordata* *subcordata oregana*
HORTULANA GROUP	*hortulana* *hortulana mineri* *reverchonii*
ANGUSTIFOLIA GROUP	*munsoniana* *orthosepala* *angustifolia* *angustifolia watsoni* *angustifolia varians*
MARITIMA GROUP	*alleghaniensis* *maritima*
SAND CHERRY GROUP	*pumila* *besseyi*

The species of the first group have been frequently confused but are nevertheless distinguished by well defined characters. Some of the varieties of *Prunus nigra* are even better adapted to certain localities than *P. americana,* and the fruit of some wild forms has a brilliant crimson coloring that I have never seen equaled in the latter species, yet largely through failure to recognize the distinguish-

[a] Bailey, L. H., Conn. Exp. Sta., Bulletin 38, 1892.

ing characters, only about twenty varieties can be definitely referred to *P. nigra* while probably nearly four hundred are referable to *P. americana*. *P. mexicana*, the southern representative of the group, is usually a larger tree and does not sucker as do the other two species. The late ripening of its fruit, being the latest of the natives, suggests the possibility of developing a late plum for the South from some of the larger fruited forms. Except by a few nurserymen in the Southwest it has not been distinguished from the hairy-leaved form of *P. americana*.

Prunus hortulana, although another species has been confused with it, is well known, and the variety Miner has been grown for nearly a century. To account for the diversity shown by this species in consequence of the improper grouping of varieties *P. hortulana* was said to represent a group of hybrids, yet when properly understood we have no more clearly distinguished species, and in certain portions of its range it is very abundant in a wild state. About sixty-eight varieties have been introduced, yet it has not received the attention to which its late flowering character entitles it in regions subject to extreme changes in temperature in early spring.

The value of another member of the hortulana group, *Prunus reverchonii*, is apparently not recognized. Unlike *P. hortulana*, it suckers freely and forms dense thickets on the black upland soils and less frequently on the river bottoms of central and northern Texas. It is apparently not regarded with much favor by horticulturists, probably on account of the astringency of its fruit. It is nevertheless extensively gathered in the wild for preserving and other uses, and occasional thickets exist which produce fruit of very fair quality. The fruit is usually red or reddish yellow, but one thicket was found on the Little Wichtia River which produced fruit identical in color with Golden Beauty. This fruit was of good quality and was remarkable in having a very small stone, about 10 mm. long and 5 mm. thick. In the dry summer of 1910 when forest trees throughout northern Texas were dying by the hundreds from drouth, this species ripened a fair crop of fruit and the foliage showed little effect of the dry season. Like *P. hortulana*, it blossoms comparatively late. This fact should lead to a thorough exploration of its range for the forms producing the best quality of fruit, and their hybridization with Japanese varieties and perhaps also with other Old World species.

In the next group *P. angustifolia* and *P. munsoniana* (Wild Goose and other related varieties) are both well known, and have been used in the South in the breeding of new varieties more than any other

native species. Varieties belonging to *P. munsoniana* have, however, been very generally confused either with *P. hortulana* or with *P. angustifolia*. Mr. T. V. Munson, for whom it is named, seems to have been the only horticulturist to properly distinguish the species until very recently. *P. orthosepala*, on the other hand, is almost unknown to both horticulturists and botanists, and its history is a curious one. In June, 1880, Dr. George Engelmann of St. Louis, sent to the Arnold Arboretum a package of seeds marked "Prunus sp. southern Texas." Plants were raised from these seeds and later some of them were sent to the Rixdorf Nurseries near Berlin, where it was seen by Dr. Koehne and described as *P. orthosepala*. It has never appeared in any American flora, and since I was unable to find anything like it in Texas the question of its origin was a perplexing one. Fortunately there were found in the Grey Herbarium of Harvard University several fragmentary specimens of a very similar form sent by Dr. Louis Watson from Ellis, Kans. A small tree in Highland Park, Rochester, N. Y., which came originally from the Arnold Arboretum, is very evidently of the same character as the plums sent by Doctor Watson. This tree bore abundantly in 1911, the fruit ripening at the same time and being scarcely distinguishable in color and shape from that of *Prunus orthosepala*. It is over an inch long and nearly of the same diameter. A plum very similar if not identical with at least some of the above was first brought into cultivation about 1878 by Mr. Abram Laire, a few miles south of Kerwin, also in the northern part of Kansas. Later, when these trees fruited they were noticed to have different foliage from either the sand plum or *P. americana*. Mr. Laire was, however, unable to rediscover the thicket from which they were obtained, and it probably been destroyed by cattle. Mr. E. Bartholomew, of Stockton, Kans., estimates that there were in 1910 at least 100,000 trees of this variety under cultivation in that part of Kansas, but neither he nor any one else so far as known has ever observed it in a wild state. It is probable that *P. orthosepala* grown in the Arnold Arboretum, the specimens in the Gray Herbarium, the Rochester tree, and the Laire all originated in northern Kansas and that they are natural hybrids of *P. americana* and the sand plum, both of which occur in this region, and of which they are intermediate in character. The fruit of *P. orthosepala* is considered excellent in quality and the Laire bears abundantly and is also considered an excellent plum. Whatever their origin, and whether they represent a single species or hybrids they are unquestionably promising for at least the plains region of Kansas and Oklahoma. They suggest too that the breeder by careful selec-

tion of the parent varieties may be able to surpass in excellence these natural hybrids.

The species of the maritima group have been but little cultivated, yet the beach plum began to receive the attention of horticulturists about the same time as *P. americana*, and its fruit is often as large as is frequently seen in the latter species in the East. At one time a variety, the Bassett, even attracted attention in the West, but it did not have sufficient merit to remain long in the field after varieties of the better forms of *P. americana* began to be introduced. Its future lies in hybridization, and Mr. J. W. Kerr has secured several hybrids which are of a vigorous character with foliage remarkably free from disease. One of these produce fruit over an inch in diameter, and though I know of none as yet of good quality there is no reason to suspect that good fruit cannot be produced if the *Maritima* parent as well as the other is selected with sufficient care.

The fact that *Prunus alleghaniensis* is so closely related to *P. maritima*, although it has but yet been utilized, suggests that it may be worthy of experiment also. A form of this species occurs in the upper part of the lower peninsula of Michigan on light gravelly ridges once covered more or less thickly with pine, and may be even more hardy. The species of the *maritima* group are in fact the only hardy native plums to grow naturally on such poor soils.

The range of our native species is such that nearly every section east of the Rocky Mountains is represented, and most of them are, for the various sections in which they occur, practically all that is required in the way of hardiness. The fruit of many of them, while perhaps inferior to that of *domestica* and *insititia*, is nevertheless distinctive and as a desert fruit some of the hybrids with *P. triflora* may eventually enter into competition with varieties originating from the domestica group. In their ability to withstand transportation, however, they are far inferior to the varieties of Old World origin, and herein as well as in the improvement of the culinary quality lies the opportunity of the breeder. Attempts at hybridization of the natives with *P. domestica* and *P. insititia* have apparently met with failure. No variety supposed to have this parentage that has yet come under my observation shows any evidence of such hybridity. Both *P. domestica* and *P. insititia* are extremely variable, and in fact many forms show differences that have caused them to be recognized frequently as subspecies or even as species. Without definite knowledge of what these forms are and which ones constitute the nearest approach to American species as well as of the relationship that they bear to Old World

species, efforts at hybridization along this line evidently will have small chance of success. It is well known that most if not all of our natives cross readily with *P. triflora*, a species undoubtedly native to some part of China—perhaps originally widely distributed in that country. Since the geographical distribution of the species of a genus usually bears some relation to the relationship of the species, and since *P. domestica* was probably indigenous to northern Asia Minor and the region south of the Caspian Sea, we may expect to find in the same region or to the eastward, the connecting species we seem to need. Unfortunately, in this case botanical literature offers little assistance. There has never been a complete monograph of the genus published in the English language, and of those published in other languages, none within the past fifty years is either complete or describes the fruit with sufficient detail to be of much use to the horticulturist. Neither does this literature throw much light on the relationship of the Old World with American species. It is impossible to present a complete synopsis at this time, nevertheless it may be profitable to mention a few of the species and show what some of their relationships are so far as can be determined from a meager amount of material.

Old world species known to produce fruit of sufficient size and quality to be of promise.

DOMESTICA GROUP	*cerasia* *domestica* *insititia* *bokhariensis* *curdica*
CERASIFERA GROUP	*monticola* *cerasifera* *cerasifera divaricata* *chapronii* *cocomilia* *pseudo-armeniaca* *ursina* *dasycarpa* (*cerasifera* × *armeniaca*)?
SIMONII GROUP	*simonii*
TRIFLORA GROUP	*triflora* *ichangana* *thibetica*
DWARF CHERRIES	*tomentosa* *humilis* *japonica*

In addition to *Prunus domestica* and *P. insititia* which belong to a group seemingly without a representative in America, *P. triflora*, *P. simonii*, and *P. cerasifera* are well known to many horticulturists. To the domestica group probably belong the less well known *P. cerasia*, *P. bokhariensis*, and *P. curdica*, although they have not as yet been studied sufficiently to place them with certainty. *P. cerasia* is a shrub or small tree producing a fruit sometimes three-fourths of an inch in diameter, bluish black in color and resembling the damson in flavor and appearance. Its origin is said to be unknown, but it is extensively cultivated in parts of Syria and Palestine. *P. curdica* is supposed to be a native of southern Armenia, and produces a bluish black fruit about one-half inch or more in diameter. *P. bokhariensis* has been confused with *P. insititia* by many authors and it apparently resembles that species in tree characters. It is cultivated for its fruit in some parts of northwestern India and in Afghanistan, reaching an altitude of 5000 to 7000 feet. The fruit when ripe is described as being large, yellow and juicy. When dried it is imported from Afghanistan into India in large quantities, taking the place to some extent of the European prune. The group of species of which *P. cerasifera* is the best known representative in America and which hybridizes with some of our native species, is apparently somewhat larger. *P. monticola* is a shrub native in the hills of northern Asia Minor and Turkish Armenia, and produces a fruit five-eighths of an inch in diameter. *P. cerasifera divaricata* is native in northern Persia and in Turkestan. Its fruit resembles the myrobalan. This form is cultivated in portions of Afghanistan, but apparently no effort is made to secure improved varieties, for it is said to be propagated from seed and not from grafts. *P. ursina* occurs in alpine regions of Lebanon and other locatities in western Syria at altitudes of about 5000 feet. It is a tree twelve to twenty-four feet high, producing a fruit three-fourths of an inch in diameter, violet-red to yellow in color. *P. cocomilia* is a tree of southern Italy apparently indigenous to Calabria, but is hardy at Vienna, Austria. Its fruit is golden yellow in color, about one and one-fourth of an inch long. It is said to be rather acid, but agreeable, and it may prove of value in the production of varieties for the Southern States. *P. chapronii* was described by Carriere in 1881, having been sent to him by M. Chapron, a gardener at Berlad, Roumania, who said it was supposed to have come from Constantinople. Carriere describes the fruit as being 45 mm. or about one and three-fourths of an inch in diameter, and although he recognized it as a distinct species, refers it to the myrobalan group. If this is a form of *P. cerasifera*

it shows much greater variation in that species than has been supposed to exist. If distinct, as believed by Carriere, it is apparently an important addition to the species having fruit of sufficient size and quality to be utilized in horticulture.

The group of species of which our only representative in cultivation is *Prunus triflora*, apparently includes two other Chinese species, *P. ichangana* and *P. thibetica*, both of which are rather imperfectly known. Material of *P. triflora* which has been collected in a wild state in China indicates that there is great variation in the foliage, and it is probably also somewhat variable in the character of its fruit. It appears to be widely distributed under cultivation in eastern and middle Asia. *P. simonii*, although so distinct from *P. triflora* as to apparently form a group by itself, nevertheless has sufficient affinity to hybridize readily with it. Several of the varieties popularly known as Japanese Plums are hybrids of it with the former species, and some of these varieties very evidently owe their excellence to the *simonii* parent. Yet all the trees of this species that have so far fruited are from a single introduction made more than forty years ago.

Two dwarf species, natives of China and more or less closely related to our own dwart cherries are *Prunus humilis* and *P. japonica*. The former is said to be frequent on the mountains of northern China and southern Mongolia. *P. japonica* appears to be of much the same general character but produces a larger fruit, and is probably more widely distributed. The bright crimson cherry-like fruits of both these species are edible. They are hardy, and crossed with *P. besseyi*, the resulting hybrid ought to be an improvement in the appearance and probably the quality of the fruit.

Some idea of the way in which these species may be utilized may be obtained by noting the natural hybrids supposed to exist and those made artificially between various members of the different groups as indicated below.

Hybrids of native with old world species

AMERICANA GROUP	*americana* × *simonii*
	americana × *triflora*
	mexicana × *triflora*
HORTULANA GROUP	*hortulana* × *triflora*
ANGUSTIFOLIA GROUP	*munsoniana* × *Amygdalus persica*
	angustifolia × *triflora*
	munsoniana × *triflora*
	angustofolia? × *cerasifera*
	(*munsoniana* × *triflora*) × (*triflora* × *simonii*)

PUMILA GROUP....... { *besseyi* × *triflora*
besseyi × *cerasifera atropurpurea*
besseyi × *simonii*
incana × *pumila*

The fact that some of the species discussed are not generally recognized as producing fruit of excellence does not need to deter the breeder. European pomologists have had little occasion to direct their attention to other species than *domestica* and *insititia,* and if they are known under cultivation at all it is chiefly as ornamentals. Unless they are very different from American species a careful exploration of the range of each will reveal great variation in the quality of the fruit. In such countries as China, Japan, and even in some portions of southeastern Europe it is chiefly the unripe fruit that is esteemed, and since there have been few introductions directly from a wild state into America, we may expect that the forms even of *Prunus triflora, P. simonii,* and *P. cerasifera* that have reached us may not be as well adapted to our tastes as other forms still to be found in their native regions.

Neither should we make a direct comparison of our native varieties with those of *domestica* and *insititia* origin. A large proportion of those now under cultivation are probably seedlings of other varieties. Those introduced from the wild have most often been the result of chance discovery. Frequently they have been found on the introducer's own farm. There has never been a systematic and thorough exploration of the range of any species to obtain the best that could be found from which to propagate. In fact, some of the species have scarcely been known in a wild state, and the range of all only imperfectly. The oldest of our varieties has probably not been under cultivation for more than a century, and in fact, the introduction of horticultural varieties has occurred almost entirely within the last fifty years. *Prunus domestica* and *P. insititia,* on the other hand, have been under cultivation for an unknown length of time. Stones of the latter have been found among the lake-dwellings of Italy, Switzerland and Savoy. Theophrastus gives directions for their planting and for grafting which possibly indicates the existence of varieties more than two thousand years ago; and their cultivation has even then extended throughout the whole of southern Europe. Coming to more recent times we find that Gerard had in 1597 "three score sorts" in his garden at Holborn, England. His were all strange and rare, but "there be in other places many more common." Although England is not a fruit growing country, the Royal Horticultural Society Catalogue contained in 1832, 274 varieties—probably more than we had named of our natives a

score of years ago. Though activity in this direction was increased to an almost marvelous extent after the publication already referred to by Professor Bailey, and we have now introduced of our natives and their hybrids more than eight hundred varieties, many of these are little better or not so good as may still be found in the wild. The real, substantial improvement remains to be accomplished.

An opportunity awaits the fruit-breeder in America, but whoever would make the most of this opportunity to develop varieties of plums better suited to American conditions must know thoroughly the systematic botany of the genus; or if he cannot be both botanist and breeder he must work with the systematist. The latter also should be in close touch with the breeder that he may clearly appreciate the character of the species or forms which the breeder requires in his work.

There should be a thorough exploration of the range of each of our native species while the fruit is ripening, that we may select only the best that Nature has produced.

If we are to greatly improve the quality of our native varieties it must be by hybridization with Old World species, but to secure any combination of *domestica or insititia* forms with our natives will require a more careful study of their relationships than has yet been made. It may be this combination can be accomplished only by means of secondary hybrids, but we may reasonably expect to find among the plums of Asia many forms well adapted to American requirements and with sufficient affinity to hybridize readily with our native species.

BUD SELECTIONS AS A MEANS OF IMPROVING CITRUS AND OTHER FRUITS

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In a visit to southern California in the spring of 1909 the writer observed in citrus groves, particularly those of the Washington navel orange, great variability in the crops of fruit borne by indivi ual trees of the same age and variety, growing under healthy cultural and comparative soil conditions. These differences had long been observed by a few citrus growers, but it had usually been assumed that the unproductive trees of one season would become the productive trees the following season, or that the differences were due to variations

in local soil, or cultural conditions, or that it was the inherent nature of the varieties to vary and that uniformity was not possible or a natural condition of varietal development. Many growers had not observed any differences in individual tree behavior until this condition was pointed out to them in their own groves.

Further study of several Washington navel groves revealed the fact that there existed not only great differences in the amount of fruit borne by trees under comparative conditions, but that there existed equally great difference in the character of the fruit borne by individual trees, and of other characteristics such as habit of tree growth, density of foliage, time of blooming, thorniness, rate of growth and other important horticultural characters. The writer found that many of the trees, strikingly variable from the standard Washington navel type, were found frequently scattered over the groves, without any degree of regularity and under all conditions. In order to assist the study of the amount of variability from the standard type, these variable trees were grouped under several heads or classes, those most nearly resembling each other being brought into a group identified by some easily noticeable character or set of characters.

A little practice in this method developed the ability to pick out the trees in a grove and classify them according to this group system without difficulty. Further experience has enabled the writer and those who have worked with him to study groves tree by tree, identify each tree according to this grouping system, and ascertain definitely the condition of the grove so far as variation is known and observable characters are concerned.

These groups the writer has termed types and will so speak of them hereafter in this article. The most important navel types found occurring frequently in southern California groves having horticultural importance to the growers are as follows:

The standard Washington navel type. This type is the most productive and regular in production of any type discovered so far. A comparison of the trees of this type and the two original Washington navel trees now growing in Riverside, shows a very close resemblance and in fact this type is made up of trees that have remained true to the type of the original trees during propagation. The habit of growth of the tree, shape and color of fruits, thickness of rind, juiciness and quality of the juice are characteristic and unmistakable. This type is the ideal one for the navel orange of southern California and produces the superior quality of fruit upon which the reputation of southern California navel oranges is based.

(2) The Washington improved type of navel, the fruit of which has a smoother, finer skin than the original Washington navel, a more red-like orange color, thinner rind, coarser rag, and at some seasons at least lacking in juice, and quality of juice.

(3) The so-called Australian navel, the trees having an upright habit of growth, more vigorous and rapid growing than either the Washington or Washington improved trees, bearing little fruit of coarse texture and frequently marked in an unattractive manner. The large trees of this type stand out in the navel orange groves so that one riding by the groves can pick them out instantly from a distance as they stand out above the other trees.

(4) The so-called Golden nugget type of navel, a pear-shaped fruit with the smooth, thin skin and coarse rag of the Washington improved type and with the opening of the navel entirely closed. The navel in this type is rudimentary or absent. The trees resemble closely the standard Washington type trees but usually bear less fruit and have a tendency to break up during any unusual weather disturbance.

(5) The Runt, or Bastard type, an unproductive type of the navel orange with dwarf trees bearing coarse fruits that are very undesirable in the orange markets and consequently unprofitable to the growers.

(6) The yellow navel type, the characteristie fruits having a pale yellow color that easily distinguishes them from the other types of navels. The trees of this type are very openly branched, possess but spare foliage of a light green color in contrast with the dark green foliage of standard Washington navel type trees. The trees are apparently light bearers, but the fruit is very sweet, slightly insipid in taste, with thin skin and infrequent red stripes or markings on the surface of the orange.

These well-defined, frequently-occurring types, in most navel groves have developed from intentional or accidental bud selections from Washington navel trees. The writer has found typical examples of all these types occurring as single fruits or as branches bearing a number of typical fruits in standard Washington navel trees where there is absolutely no possible doubt of their being natural bud variations. In addition to these frequent types, many infrequent bud sports of peculiar and widely different characteristics from the type mentioned above have been found. In this brief paper it is impossible to discuss these infrequent bud mutations, but their presence in our citrus groves proves beyond reasonable question of doubt the possible and probable origin of new types and varieties of citrus fruits from this cause. It may be mentioned in passing that some of these bud

variations have been propagated by nurserymen and others, varietal names given, and in some cases at least, unusual and fanciful methods of origin supplied which are misleading and obstructive to the real work of improving the navel orange in production and quality of fruit.

In pomelos only one variety, the Marslis seedless, has been observed so far in connection with our work. Similar typical differences have been observed to those in the navel orange. Two main and important types have been found that stand out clearly and are of commercial importance, viz; the so-called Ideal type, the trees of which bear slightly flattened fruits, with ivory white color of skin, thin rinds and delicate rag, and are very heavy producers; and the so-called seedling type, the trees of which bear more rounded fruits with thick, and rather rough skins, and are very light yielders at any time. The fruits of the seedling type contain many seeds, averaging perhaps fifty seeds per fruit, while the ideal type fruits contain but few seeds, probably not more than two seeds per fruit in the average.

In lemons only one variety has been studied thus far, the Eureka lemon, the leading variety grown in southern California. In this variety the types of trees are so clear cut and marked, that after once seeing them a novice can designate the trees of each type as they occur in the groves. One of these types is a regular bearing type producing about an equal amount of highly desirable fruit every month in the year. As can easily be imagined the total yield of trees of this type is very large, making it a most valuable commercial type. In extreme contrast with this type we find a considerable percentage of trees that we have called temporarily the shade tree Eureka type. The trees of this type are much larger than the trees of the regular bearing productive type and from this character alone can easily be picked out in all Eureka groves. The trees bear crops only during the late summer producing one or two picks in comparison with the twelve picks of the productive type, during the year. In storage the fruits of this unproductive type cure into rough, thick-skinned fruit, undesirable and with little juice. About 75 per cent of the fruits of this type are second grade, while we have found that about 75 per cent of the productive type fruits are first grade. The difference in value of the fruits of first and second grade is about, roughly speaking, $1 per box. A third type of Eureka lemons is made up of rather dwarf trees with abundant and dense foliage and yet more unproductive than the shade tree type. A fourth type is characterized by peculiar pear-shaped fruits instead of the oval shape of the typical Eureka lemon. A fifth type bear absolutely seedless fruits at all seasons while the other

Eureka fruits vary in number of seeds from three to fifteen per fruit, in certain seasons, while the fruits reaching size for picking in other seasons are practically seedless. Another type has variegated leaves and fruit, alternating sections of white and green. These differences in color in the fruits tend to disappear in curing. These and other types of Eureka lemons vary in thorniness, in number and size of thorns, in time of blooming, in habits of tree growth, in shape and color of fruits, in thickness of skins and amount of juice. It is impossible to mention, let alone describe, the many bud variations in this variety of lemons in this brief general paper. Their importance may be appreciated somewhat from the fact that in a coöperative experiment it was found that the productive type of tree produced in one year, 200 packed boxes of lemons more per acre than the average of all other types of this grove, the increase having a money value of about $800 per acre. From this carefully and accurately conducted experiment, the importance of uniformity in type, the propagation of productive and desirable types of lemons, and the immense importance of bud variations to lemon growers can be somewhat understood.

In the case of the navel orange, the pomelos and the Eureka lemons the most productive types of trees produced the most valuable fruit from the standpoint of commercial quality, i.e., size and grades. Not only was this true, but the most productive individual trees in these types carried out this general principle, viz: that large production is accompanied by high quality. This fact was a surprise to the writer, and to many citrus growers, but our data absolutely proves this point without exception and a careful observation of select trees of varying productiveness will disclose this fact to any observer.

The writer has experiments under way that will demonstrate the feasibility of rebudding any or all of these types in established trees. Some evidence is now at hand showing conclusively that some of the unproductive trees and types can be rebudded to productive types successfully with little temporary loss to the grower and large ultimate gain. Other experiments in propagation of types and desirable or select individual trees of these types are under way and some are planned for the immediate future. In this case also, there is some valuable evidence that the present types and individual tree characteristics can be propagated by bud selection based on actual tree performance records.

If, as the writer now believes to be probable, the unproductive types and individual trees can be eliminated by rebudding, the yields of our established citrus groves in southern California can be increased

from 25 to 75 per cent annually and the value of the crop increased 50 per cent through the improvement in the grade of fruit.

In connection with this work the writer has carried on some observations with peach varieties in Connecticut, viz: the Carmen, Elberta, Belle of Georgia, and Selah varieties. In 1910 these varieties had an "off" season of light crops. In a visit to the Hale orchards the writer observed that while the trees of these varieties bore light crops as a rule, the individual trees here and there, possibly 10 per cent of the orchard, bore heavy crops. In order to further observe the behavior of these trees systematically, plots were laid out about some of these heavy fruiting individual trees in all of the four varieties. Of course care was taken to secure comparative plots and trees so that no question could ever arise in this connection. The yields in 1910 varied from fourteen baskets for the heavy-yielding trees to one-half basket for the light producers. The product of each tree, as in the case of the citrus experiments, was graded and each grade weighed and the fruits counted. The largest yielding trees that season yielded the best fruit. In 1911 similar performance records were obtained. Without a single exception the heavy yielders of 1910 were again the largest producers in 1911. The light yielders of 1910 gave greatly increased yields in 1911, varying in increase of production from 25 to 75 per cent over 1910, but the significant fact remains that the large producers of 1910 did not in a single case in these plots fall off in yield in 1911. The heavy yielding trees in 1910 and 1911 had been thinned while the light yielders of 1910 were not thinned in preparation for the 1911 crop. The writer has not had the opportunity to study the typical differences in peach varieties as in citrus fruits, but in the Carmen variety he has distinguished four distinct types and propagated from each. Is it not possible that in deciduous fruits we may have regular bearing types and irregular bearing types of trees as is the case in citrus fruits? If so, the propagation of these regular bearing types will add tremendously to the profitableness and certainty of deciduous fruit growing.

In conclusion the writer would like to urge more investigation of this subject by scientists and horticulturists. A careful performance record of comparative individual trees of established varieties for a period of five years, accompanied by close and intimate observation will be well worth while. I am of the opinion that there is more need for improved established varieties than for the creation of new varieties of horticultural crops. Many interesting and important related problems will undoubtedly develop during the course of this study.

One of these is the influence of the stock or scion. So far as this related to bud propagation, only congenial stocks may be considered. The ability to transmit bud mutations and variations by bud selection disposes practically of the theoretical importance of this phase of the subject. I am of the decided opinion that the securing of adequate performance records will be found to be both a pleasure and a profitable matter and will become a regular feature of horticultural practice when once its full importance is recognized. The writier would recommend a plat of not less than five, preferably one hundred trees for this purpose, numbering each tree plainly by painting the numbers on the tree trunks, and grading the fruit of each tree carefully as picked in the orchard. The weight and number of fruits of each grade should be recorded in a record book wherein a series of years of records can be kept in regular order. The only apparatus needed is a pair of scales capable of weighing from 1 ounce to 500 pounds, which can be purchased for from $10 to $25. Photographs will add to the value of these records but are not absolutely necessary, as the data will tell its own story. The writer will be glad to assist in planning work of this kind so far as his ability and official duties permit.

PRINCIPLES RECOGNIZED IN THE BREEDING OF CEREAL PLANTS AT SVALÖF, SWEDEN

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It is not my intention in this paper to give an exhaustive account of the work which is being done at the famous Plant Breeding Institution at Svalöf, but rather to present as briefly as possible a description of those principles which are at present recognized in the production of more useful forms of cereal plants at that institution. It should perhaps be stated at the outset that the exposition of these principles as here given represents the results of a special inquiry by the writer, who spent several months at Svalöf with a view to obtaining first-hand information as to the nature of the work which is being prosecuted at that place.

It need scarcely be stated that the principles which are now recognized and applied by the Swedish experts are not the principles which were recognized at the beginning. In all progressive work, especially such work as has to do with life, new experiences and the accumula-

tion of new data are likely to bring new conclusions and give birth to new principles. Such is the history of the work at Svalöf. When this work first began, the development of better sorts was sought through the application of a system of continuous selection according to which one sought to change the sort in its entirety in a certain desired direction. This principle assumed the omnipresence of hereditary variations even in such self-fertilizing plants as wheat, oats, and barley, and, in accordance with the Darwinian idea, it was believed that definite and substantial improvement could be effected by selecting plants which seemed to vary in certain desired directions. The unit of improvement was therefore the "group" of plants, which was selected *en masse* according to a presumably superior type. This system of selection was commonly called the system of *mass-selection*.

While the old idea that all plant life is constantly in a state of unrest —varying this way or that—and that such variation is hereditary in character has had to be modified, yet the original system of mass-selection was by no means without results and has in fact never been entirely abandoned. Greater uniformity, higher yielding capacity and, in autumn wheats, greater hardiness were the ultimate rewards of these early endeavors, although it required several years before the extent of this improvement became fully demonstrated. So long as the operator confines his selection to mixed or composite varieties, that is, varieties which consist of two or more strains of varying practical value, it is regarded possible, in most cases at least, to effect an improvement by the application of this system. This improvement is due to the exclusion of inferior strains and to the inclusion of only those which conform to the desired type. In this way there may also be gradually obtained a relatively pure group.

While the efforts to effect improvements upon certain old varieties of cereals by the system of mass-selection were therefore by no means futile, yet at the end of the first five years' work the various cultures did not measure up to the standards of constancy and uniformity which had been set at the beginning, but each generation continued more or less heterogenous. This served to introduce more exact methods and a more careful examination of all types dealt with. Hundreds of apparently distinct types were selected from the common varieties and the seed from each group sown in separate plots. In four or five cases single plants or heads seemed to have no duplicate. When the seed from these was sown and the resulting plants approached maturity, it was seen that these and these alone of all the hundreds of cultures were uniform in character. This discovery

served to introduce the so-called system of separate or pedigree culture by which the *single individual* constitutes the starting point for new sorts instead of the "group," as in the older system.

In the isolation of individual plants only those individuals which were *morphologically different* were at first taken, as it was supposed that certain morphological or, as they were then called, "botanical" characters were definitely correlated with certain practical qualities. Thus great weight was attached to such points as the position of the branches of the panicle in oats, the number of kernels in the spikelets and the density or closeness of the head in wheat or barley. In the latter case compactness of head was supposed to be correlated with stiffness of straw. In selecting for stiff-strawed sorts, the character of the head was therefore accepted as an indication of the degree of stiffness by which it was characterized. This idea however came to be modified later. Many interesting illustrations might be cited of the manner in which the choice of mother plants came to be influenced by certain peculiar characters or marks which they happened to possess. This idea of form separation (Formentrennung[a]) had been applied by Le Couteur and Patrick Shirriff of England many years before but at Svalöf it was introduced on a much larger scale. At first it seemed that this system was capable of being developed to a high degree of perfection. If practical qualities were indicated by or correlated with botanical characters, the problem of the breeder must obviously be to ascertain first of all just what character is correlated with a given quality. This accomplished, the isolation of superior mother plants as starting points for new and improved races should be a comparatively simple matter.

Unfortunately experience came to show that the practical value of a sort cannot be judged on the above basis with any degree of certainty, neither can the most desirable mother plants be always isolated in a mixed population on this basis alone. Two main reasons are submitted in explanation of this fact. In the first place a plant may be temporarily modified by external factors to such an extent as to cause it to assume quite an altered appearance. While the character thus temporarily acquired may be a promising one, yet the fact of its instability renders the selection of such plants uncertain. In the second place, physiological qualities of special value which may characterize certain individuals which do not possess striking morphological characters and which give little suggestion as to their real practical

[a] Fruwirth.

worth. These discoveries served to introduce a second method of applying the pedigree method of selection at Svalöf. Thus instead of basing the isolation of superior individuals purely upon morphological characters, the principle has become to select a *large number of individuals without special regard to these characters.* Where formerly only a comparatively few distinct *forms* were taken the present practice is to take *a large number of individuals,* no matter whether they resemble each other or not. The valuation of the majority of these individuals in so far as yield is concerned is determined by yielding tests conducted with the greatest possible care. This change in method brought with it a still further alteration in the general course of procedure at Svalöf. Thus where formerly mother plants were selected wherever they could be found, and without special regard to the variety in which they were growing, they are now taken only from well known varieties whose values have been thoroughly proven.

ARTIFICIAL CROSSING

Following the application of the pedigree system of selection at Svalöf, the enormously composite character of many old varieties quickly became disclosed. So abundant and promising were the constituents (bio-types) of these old races that it seemed quite unnecessary to adopt artificial means of producing a greater variety. It seemed in fact that nature had already provided sufficient material to meet all the legitimate demands of practice. Here again experience seems to have taught otherwise. True, progress has been made in the isolation of superior sorts from old mixed races by simple selection, but this progress has been achieved after repeated disappointments. A discouraging and noteworthy feature in connection with the work of predigree selection with cereals is the difficulty of finding a bio-type in nature which combines the best of all qualities in the one individual. It has indeed been a matter of common observation that very frequently pedigree sorts are outstanding in respect of certain qualities while they are conspicuously weak in regard to others. Artificial crossing has therefore come to be employed as a means of combining the desirable characters of one sort with those of another.

Since the reappearance of Mendel's epoch-making papers on hereditary in 1900, great progress has been made at Svalöf, both in the acquisition of more exact knowledge of fundamentals and in the practical application of advanced principles generally. The "combinations" idea which is a central doctrine of Mendel's law has come to entirely

supersede the old Nägelian idea of crossing, thus placing the whole problem in quite a different light.

The principle of combining parental characters demands that great care be taken in the choice of parents. Neglect of this rule during the early years of the work at Svalöf is believed to account very largely for the indifferent success which attended crossing efforts during that period. The desirability of handling products of *known origin* is another factor which has served to bring artificial crossing into greater prominence in breeding work, since the origin only of the products of this process is capable of being traced. The parentage of the constituents of mixed races must on the other hand be largely an unknown quantity, thus rendering the work in line-breeding a more or less uncertain and indefinite one.

An excellent example of the usefulness of artificial crossing in breeding work is afforded in the production of Extra Square Head II autumn wheat at Svalöf. One of the main problems in autumn wheat breeding in Sweden has been to obtain a sort which would be sufficiently hardy to withstand winter-killing, and which would at the same time be more productive, stiffer in the straw, and more resistant to disease than the old wheats commonly grown in the country. Many pedigree sorts were isolated and investigated and a few discovered which were undoubtedly superior to the old races. Two of these, Extra Square Head and Grenadier II, were especially noteworthy. While these sorts are very similar as regards general character, they have been found to differ in certain important particulars. Thus the former is more hardy and less susceptible to rust than the latter, while the latter in turn has shown itself to be a higher yielder and stiffer in the straw than the former. These two sorts were crossed artificially, and, from among the numerous combinations resulting, one, to which the name Extra Square Head II was finally given, was found to unite a greater number of desirable qualities than those possessed by either of the parents. During a four-years' test at Svalöf and Alnarp this sort has given about 18 per cent higher yield than Old Extra Square Head and 8 per cent more than Grenadier II.

From this brief review of the principles recognized in plant improvement work at Svalöf it will be seen that all possible ways of reaching the desired end are employed. Line breeding, artificial crossing, and mass-selection each occupy a place and may indeed be regarded as the tripod of progression in the scientific breeding of plants.

THE IMPORTANCE OF MAINTAINING A CONSTANT ELIMINATION FACTOR IN ASSOCIATION WITH A CONSTANT NUTRITION FACTOR IN PLANT BREEDING

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I shall not at this time present statistical data on the subject matter of this preliminary note. It is given at this time merely as a suggestion. It is a feature which, perhaps, every plant breeder has had fairly well in mind, though he may not have been thinking of it in the same manner or along the same lines. It is evidently the thought of almost all workers in cropping and plant breeding work that an experiment in testing out varieties or strains in a comparative way has little value unless the various conditions of cropping are reasonably similar for the tests or trials which are to be compared. Naturally this thought has caused those who are engaged in breeding work to give reasonable emphasis to preparing conditions of cropping which shall be rather uniform. However, most plant breeding work, and more especially in cereal crops, has been conducted with but slight concern as to the factors mentioned in the title of this paper. The reverse is, perhaps, more often the case than otherwise. Most agronomists and plant breeders, especially of cereals, have followed rather persistently—indeed, the writer thinks, quite too persistently—the old theory that best results may be gained by placing the seed under trial conditions of the most favorable sort for the development of an all-round plant; that is to say, they have usually prepared garden conditions upon which to develop a strain or variety; conditions which they believe will furnish all of the most desirable food relations for the particular crop. That is, conditions which appear to them apt to furnish the most satisfactory arrangement of all the ordinary nutrition factors. Even then, it can, perhaps, quite truly be said that in most cases such tests have been seldom twice on the same soil. Often the investigators seem interested in giving the seed a change of soil, as though they might fail of variation if this change of soil were not available. Indeed most such workers contend that under soils of most fertile and varying character the crop is most liable to vary from the type under consideration. The writer has not believed that these supposed ideal conditions are the most satisfactory under which to conduct breeding operations and selecting

operations with cereal crops, and, as has been reported elsewhere, has, for a number of years, been working with the point in view of developing conditions adverse to the supposed best cropping conditions. For example, instead of making studies upon variation of wheat, flax, and other cereals under the most satisfactory conditions of soil fertilization, soil cultivation, and crop rotation, many of the trials have been conducted upon and under conditions of continuous cropping of the soil by the same crop and under conditions in which certain definite modifications are maintained.

The gardens have been kept in the same place, but definite changes have been made in the conditions of certain beds. Always, however, the attempt is made to retain for a series of years one or more factors as constants. The particular variety is also tried under normal cropping conditions and under a number of other trial conditions for purposes of comparison. It has been the thought of the author that no matter in what manner variation may arise so that new characters become apparent, these new characters have, at some time, had to arise because of changed conditions or changes in conditions to which the parent plants have been subject, and it has been my belief that features of environment which involve the presence or absence of constant factors in nutrition have much to do with any changes which may take place, whether we speak of them as "fluctuating variations" or as apparently "fixed mutations." This would indicate that the writer has not seen sufficient evidence to prove that so-called unit characters or the elementary species of the Mendelian school do not vary as in the case of any other of the less "segregated" or *rather less apparent* types. It would also indicate that the author is not convinced that so-called acquired characteristics are not, under certain conditions, heritable.

Indeed these considerations prompt the writing of this short note. The writer thinks he has seen in his study of pure-bred types of flax and of wheat indications of changed character which must be inherited from year to year, which features of accumulated character could not have been observed had it not been possible to introduce a constant feature of elimination. The writer believes that whatever our investigations finally center upon as the real cause of the origin of immunity or resistance to diseases it will eventually be found that such immunity or resistance has been transmitted—inherited in exactly the same sense as any other character which reproduces itself in a morphological or physiological form. It would appear to have been shown by Biffin and others that such resistance to disease tends to

follow the so-called Mendelian laws of dominance and recession. Our own experiments in cross-breeding flax and growing upon flax-sick ground seem to bear out that conclusion, for flax is a closely inbred plant, and the writer has never seen any good evidence that a pure variety ever crosses in nature. Wheat also is a closely inbred plant, and the author has never seen, to his knowledge, a clearly proven case of cross-breeding in nature, though I admit freely that it seems strange indeed that such fine opportunity is given for the interbreeding of such plants and I would not assert that it never does take place. Possibly the time may come when we may have clear evidence that such crossing does take place in nature. Even then these observations will scarcely have lost bearing or importance, for an accumulative quality is apparently transmitted in the cross-breeding. The writer conducts a few experiments in cross-breeding every year, and very extensive experiments in selection with a view of obtaining types of cereals more resistant to disease. We have reached astonishingly satisfactory results with the flax plant, having obtained plants both resistant to wilt and rust and apparently in a large way resistant to some of the other more indefinite diseases of the crop. With this crop I know how the resistant stuff has been obtained, and the observations lead me almost to believe in the hereditable character of "acquired," or, better, accumulative characteristics, regardless of all that has been said and done in late years to prove the contrary, and regardless of my own early convictions as based upon the doctrines of Weismann.

(1) My first observation is that I can get a resistant type or strain of flax from almost any known variety.

(2) It is much more difficult to induce that resistance in some varieties or strains than in others, but eventually it may be procured in a high degree and in what would seem to be an astonishingly short time, whether we select from mass or from the progeny of a single seed. *The important factor in the process is the constant factor of disease* attack.

(3) In beginning the work I may say that I have never been able to procure what anyone would call a full-fledged wilt-resisting flax plant in the first generation; that is to say, the first generation after selection has never been able to produce anything but what in rough language would be considered scrubs. Sometimes in four or five generations, sometimes in six, eight, or ten the final product brings forth essentially a normal crop on the sickest of soil—*upon a type of*

soil on which originally the parent seed could not have produced perhaps a single plant to an acre.

(4) Then it is evident that the *resisting ability increases from year to year, from generation to generation*, even in a pure, pedigreed strain which came originally from a single non-resisting seed. To illustrate: Knowing of a high-yielding type of flax which gives large yields of seed or the type of straw which is desired when growing on land free from the flax diseases, the writer has found that it is seldom possible to procure any plants if the seed from such non-resisting crop is placed upon the most thoroughly sick soil. The way to get started in this work is to plant the seed of such non-resisting crop upon a soil which is but thinly or poorly infected or infested with the root diseases of flax; or, to plant it on new soil and partially infect the plants with diseases during the growth season.

(5) The author is convinced that to procure resistant flax from non-resistant strains it is necessary to procure seed from sick plants or at least from plants whose roots have been attacked; or at least which were growing in ground which has been infested with the particular root disease concerned.

(6) We have now worked upon the flax proposition long enough to assert without fear of contradiction that a particular strain of flax which has a certain grade of resistance will not lose that resistance if the seed for each following generation is sown upon land in which the disease is abundant and in which the conditions which are favorable to the disease are more severe than those in which the parent plants grow; and the seed from such parentage can be carried to soils which, year by year, furnish more destructive conditions of disease production.

(7) This can, apparently, mean only one of two things: Either that the so-called unit character of resistance was present in an undeveloped form and becomes stronger and stronger from year to year under the conditions of disease, or *that there never was any character there which is entitled to be called a unit character but that it began to develop the first year its parent plants came in contact with the disease, and the protoplastic nature of the ancestry of the plants which we now have has been such that they have accumulated more and more resisting power from year to year just in the proportion in which they have opportunity to develop that resistance against a constant acting factor of disease which when too powerful acts as an eliminating factor.* The writer does not know but he is inclined to believe that considering the points above

stated and the observations upon which they are based the last feature is the true observation, for it must be remembered that in this work I am dealing not with selections from bulk but selections from year to year from the progeny of a single seed.

(8) Another element which indicates this line of thought quite clearly centers in another method of experimental work. The author has found that many conditions influence the virulence of the diseases. For example, he learned that the presence of barnyard manures or a high nitrogenous content in a fertile soil heightened the abundance or development of the disease and apparently increased its ability to do harm in the same sense as has previously been recorded for potato scab. I therefore started to add barnyard manures to old flax-sick soil to help along the elimination process, planting one or more resistant strains under those conditions. Later I found, as in the case of potato scab, the addition of alkalies, as for example, potash fertilizers, lime fertilizers, wood ashes, kainit, etc., aided the root diseases in their destructive ability. When under the condition of the presence of one of these fungus-invigorating applications to the soil we were able, nevertheless, to select a poorly developed resistant plant, it has been found that such a plant the next year has had resistance to the disease much in excess of that previously noted for that strain or selection.

After I had succeeded in procuring wilt-resistant plants I later found that I had strains of wilt-resistant flax which, though of high worth in resisting wilt and the root diseases, were essentially of no value in resisting rust. Yet, working in those same strains and others which show less wilt resisting powers but high rust resisting powers we have at last been able to turn out flax which neither rust nor wilt can, apparently, affect. For example, this year, one strain has produced approximately 32 bushels of seed per acre on the most wilt sick land, perhaps, in the world, and the sixteenth consecutive crop on the same land and at the same time, surrounded on all sides by other strains of the most non-resisting rust type, strains of flax which were defoliated by rust early in the season. Most of these resistant types of flax which have been in the hands of farmers for four years show that they retain their resisting ability in varying degree. They retain it sufficiently for all of the farmers to be extremely well satisfied, but when the seed is returned to the old ground from which it comes it is found to be resistant in varying degree according to the conditions to which it has been subjected. In some cases it comes back apparently improved in its resistance, in other cases it comes

back essentially spoiled, but in the latter cases we have observed that the difference in resistance is due largely to the matter of physical injury to the seeds themselves under harvest conditions. Perhaps, however, we shall later find that such seed after several years upon land in the absence of the constant disease factor in association with factors of nutrition which are highly favorable to disease production will have lost in resistance. This problem remains to be settled. So far as flax is concerned the feature which is made plain by the experiments is that in order to get the highest quality of resistance developed it is necessary to maintain certain constant factors, one of which is the constant presence of the diseases and another of which is a nutrition factor of constant type. For example, a flax which has had its resistance developed upon a soil highly nitrogenous and highly infected by wilt is not as strong in its resistance to disease when grown upon a soil of light nitrogenous content as a strain of the same breed of flax which has been under the same conditions of disease on a similar soil of poorer nitrogen supply. A strain of resistant flax which has been developed on a soil of high water content in the presence of disease is not as valuable a resistant plant to grow on a dry soil in the presence of disease as a strain of the same origin which has had several years of contest with the diseases on a dry soil of like character. A strain of flax which has had its resistance to wilt developed upon a highly alkaline soil consisting of potash and soda has a high grade of resistance to disease on soils of similar character which is not found in a strain of flax of the same pedigree which has for a number of years been grown upon a similar soil of less alkaline conditions or in soils of low potash and soda content, etc.

In regard to developing resistance in wheat to rust, the writer met with but slight hope of success until he had gained this insight with regard to the action of various diseases which wheat is heir to, including the root and internal seed diseases, and by maintaining constant elimination factors through the introduction of the various disease factors and through the maintenance of soil conditions which are associated with the diseases of the wheat crop, which seem to be capable of essentially destroying the crop, the author believes that he sees the road to the attainment of wheat of real merit in disease resistance. In other words one will not be apt to procure rust resistant wheat by any type of cross-breeding or selection which is conducted in the absence of rust or in the absence of those conditions which develop rust. It is a fact which I clearly demonstrated in Indiana in 1888 and which has been observed by many parties since, that the

presence of highly nitrogenous nutrition factors tended to make wheat non-resistant to rust, or rather tends to high development of rust. It is under such conditions, however, acting as a constant elimination factor and a constant nutrition factor, that breeding and selection, whether it be done by straight selection or by cross-breeding, will be apt to furnish us the plant which we are all looking for; namely, a rust resistant wheat plant for such conditions. The writer believes that if a constant nutrition factor is held against the development of a plant and an intelligent eliminative selection is exercised in association with it, there is great hope of procuring any type of plant which is desired and that while cross-fertilization and the rules of Mendelian philosophy of heredity may greatly aid the work, I feel sure that great gain can be procured and maintained without it, at least in the closely inbred cereals. Further, I believe that without maintaining one or more constant factors of elimination and constant nutrition factors in association therewith there will be slight gain that may be expected from ordinary selection for the improvement of crops and especially cereal crops, whether one is working for the production of drought resistant types, disease resistant types, or simply types of better yielding capacity for particular climatic and soil conditions. It would seem that this is the real explanation of why home grown seed is better than the same pure-bred variety which has had a vacation away from home for a number of years or any other grain of similar breeding which has been brought in from a home of dissimilar conditions. To make clear what I mean, the conditions which one wishes to select against must be severe, must be rigidly maintained, and then one may hope within a comparatively short time to obtain a type of resistance to those conditions which may be carried on to the ordinary farm in such shape as to prove of economic importance. *If these conclusions are correct, there are probably no unit characters which are not fluctuating and there are no fluctuating characters which may not become reasonably "fixed."* Time coupled with the constant factor or factors (*stimulus or stimuli* as the case may be) is the factor in all of these matters which is the deciding element. From the side of the practical agriculturist the feature of hope and encouragement is that when once attained in high degree any of these characteristics may be maintained and improved through careful agriculture.

REPORT OF COMMITTEE ON BREEDING NUT AND FOREST TREES[a]

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This year's report indicates, as did that of the last meeting, the principal lines along which improvement of forest trees must follow, and has followed during the past year, as a basis for future work. The report also surveys the main achievements in tree breeding accomplished here and abroad during the year, while in addition individual members of this committee have presented separate papers on special subjects relating to tree breeding.

The committee still holds its previously expressed view that the only way of immediately improving the quality of timber is by a judicious selection of the sources of seed and by introducing new species into localities in which they may prove superior to native stock.

SOURCES OF SEED

The committee has already reported a number of experiments made at the Forest Stations in Colorado and Arizona regarding the effect of the source of seed upon the resulting seedling, the species used being western yellow pine and Douglas fir. Similar experiments were carried on this season with western white pine and western larch at a newly established station in western Idaho. Experiments in this phase of tree breeding are of immense and immediate importance in the work of reforestation. It is not, in most cases, a matter of breeding up the species in any locality by a selection through several generations, but a single selection from which results may be expected almost as soon as seedlings can be made to grow.

Some of the problems encountered in selecting the source of seed are:

(1) Is it advisable to use in one locality or forest seed collected in another forest which may differ somewhat in latitude, precipitation, or character of soil? Incidentally, the extent to which the source of seed may have a bearing on the success of direct seed planting work,

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determines the procedure to be followed in collecting seed, in centralizing seed-extracting operations, etc.

(2) Do trees which are especially heavy seed bearers necessarily produce the most thrifty and vigorous seedlings? If so, seed collecting should undoubtedly be restricted to such trees as much as possible.

(3) Are certain defects of parent trees which may, in some instances, make them prolific seed bearers, and thus especially attractive to seed collectors, likely to be transmitted as weaknesses, to their offspring, and are the defects in the technical quality of the wood hereditary or purely the result of external conditions of growth? There is much evidence to show, however, that defective qualities of the wood are transmitted as weaknesses. If this should be finally proven, every effort should be made to avoid use of seed from imperfect trees; otherwise we shall not improve the quality of our timber while reforesting the immense areas of burned and cut-over lands.

These and other similar problems are only different phases of one problem—where and how shall the seed for reforestation work be selected? In order to answer this question a comparative study was made this year at the Fort Valley Experiment Station, Colorado, of one hundred western yellow pine trees of different ages and conditions with respect to the quantity of seed produced; and also at the Fremont Station, Colorado, where a number of plantations of western yellow pine and Douglas fir have been established to show the quality and climatic adaptability of the seedlings grown from seed of the same species from different sources, as well as of seed of the same species from especially vigorous and from unthrifty trees, in order to determine what character of seed may most profitably be collected for reforestation work in various localities. While these experiments will have to be carried on for several years before they can yield conclusive results, nevertheless some conclusions may be drawn even now. Thus it has been fairly well established with regard to the western yellow pine, that:

(1) The average germination per cent for seed of young trees was 76 against 68 for seed of mature trees.

(2) The germination of seed of all trees from 140 to 250 years was 8 per cent higher than that for trees 250 to 400 years old.

3 Seed of trees with dead top branches or basal burns show a higher germination than that from healthy uninjured trees.

(4) Seed of trees affected by mistletoe and bark beetle show a germination 31 and 17 per cent, respectively, below that of unaffected trees.

(5) While the germination of seed from trees of medium age is below that of young trees, the older trees are to be regarded as the most efficient seed producers because of their larger size and consequently heavier yields.

STUDIES OF RANGE EXTENSION

With respect to the introduction of new species into localities in which they may prove superior to stock native there some progress has been made. Some of the problems encountered in studies of range extension are as follows:

(1) Are the most rapid-growing climatic forms of a species adaptable to change of environment, and, if so, will they prove more valuable than the native form of any locality, or will they immediately revert to the same form and rate of growth?

(2) In the introduction of species to a new region, such as the Nebraska sandhills, where all forest trees may be considered exotics, many unexpected natural enemies appear. Climate, however, is probably the most important factor in success or failure. Despite all efforts to care for seedlings in the nursery, to protect them from disease, excessive light, and drought, and despite also the efforts to make the conditions at the time of planting as favorable as possible, results so far obtained indicate that in such a given situation only a certain small proportion of the seedlings planted of any species will survive. Failure to adapt themselves to new conditions would seem to be the only possible explanation. Can, therefore, the quality of adaptability or original hardiness be traced to the parent trees?

In this connection it is worth while to go farther in detail than was done in last year's report into the object and significance of this particular phase of tree breeding.

In the mountainous regions within and outside the National Forests are found several distinct forest types in separate altitudinal zones.

The principal differences in climate between these successive zones is the amount of precipitation which they receive, and, less important, is a decreasing mean temperature toward the higher altitudes. To what extent the amount of moisture present in the soil, and the air temperature absolutely limit the altitudinal range of a species, and to what extent this limitation of range of any species is due to the more successful competition of another species, is still a matter of speculation. It is believed that any species is capable of adapting

itself to less moisture on the one hand and lower temperature on the other hand than are peculiar to its native habitat. Such being the case, it is possible that western yellow pine and Douglas fir, by far the most valuable of the Rocky Mountain species, can be made to grow in place of the much less valuable pinon pine on the one hand and the less useful Engelmann spruce on the other hand. It is understood, of course, that there is to be no competition between the natural species of the type and the species whose range is extended into that type, the problem being to create new types of forest growth more valuable than the natural types.

To answer this question, two experiments were inaugurated at the Fremont Station, Colorado, for the extension of Douglas fir by artificial sowing and planting to higher altitudes and with the extension of yellow pine to lower altitudes than either grow naturally. These experiments, if serving no other useful purpose, will furnish more definite information than is yet available regarding the climatic limitations of successful reforestation.

What is true of altitudinal range is also true of horizontal range. There are many species occurring in some sections of the west which are absent from others, although the climatic and physical conditions may be nearly the same. Thus, lodgepole pine is absent from the southeastern portion of the Rocky Mountains, where there are many localities in which apparently it could grow well.

Experiments were also instituted in several of the National Forests, and especially at the Fremont Station, for the purpose of testing the introducing, by seeding and planting, such species as eastern white pine (*Pinus strobus*), western white pine (*Pinus monticola*), lodgepole pine, Norway pine, and several others which naturally do not occur there, but whose climatic and soil requirements do not differ essentially from those of the other species growing naturally in these localities.

While the Forest Service is not greatly concerned with the introduction of foreign species in this country, believing our own forest flora is so rich in species that it is possible to find trees practically for any situation and soil, yet there are a few foreign species the economic importance of which is so evident as to demand experiments for the purpose of determining their suitability to this country. Among such species are cork oak, maritime pine, Austrian pine, Scotch pine, European larch, Norway spruce, eucalypts, and acacias (wattles).

Eucalyptus planting in Florida.—As a result of investigations during the winter of 1910 (published in the Forest Service Bulletin 87) the Forest Service made several experimental plantations of eucalypts.

These experiments will be continued and extended during the coming year in order to determine the fitness of certain eucalypts for planting in Florida.

Much experimental work has also been done by the Forest Service on the Florida National Forest, where over two acres of cork oak has shown exceptional adaptability to the region, holding out a promise that this species, which is the world's chief source of commercial cork, may become established in this part of the United States.

Still another experiment in the introduction of foreign species which promises much in the way of helping to solve the reforestation problem in the longleaf pine region of our South, is the growing of maritime pine in Florida, a tree of southern Europe from which French naval stores are obtained. Seed of this pine were sown, on about ten acres, at East Bay Ranger Station on the Florida National Forest. In spite of the exceptionally dry spring, this seed germinated well and the seedlings have so far made good growth. Should the seedlings continue to maintain themselves, larger plantations may be made. The cheapness of the seed, the rapidity of growth, and the excellent qualities of the turpentine obtainable from this tree and of its wood make the maritime pine a desirable species for our southern pine belt.

Study of acacias (wattles).—During the past year an economic study of wattles was made by the Forest Service. In this investigation the species which are most valuable for tanbark and timber were studied. Many of these acacias have been successfully cultivated in California for periods from twenty to fifty years. However, none of them have as yet been planted in this country on the commercial scale which the value of their products and the evident adaptation of the species to large areas clearly justify.

The Chinese pistache has also been planted in the foothills of southern California with fair success, which makes advisable further experiment with this species.

BREEDING NEW STRAINS OF BASKET WILLOWS

Of all trees, the willows which are used for basket making and other willow-ware lend themselves particularly to breeding by hybridization. Willows now used for basket making are of European origin, our native species being considered inferior for high-grade work. It is the aim of the Forest Service, however, to develop several native osier willows suitable to different regions of this country, and with this object in view cuttings of practically all of our native willows

were planted, together with a number of exotic species. The salicetum thus established is at the Arlington Experimental Farm, of the United States Department of Agriculture at Washington. In all, some 107 species were planted and are now being studied.

THEORY OF ACCLIMATIZING TREES

A lively discussion has arisen during recent years regarding the possibility of improving forests through the selection of seed and by extending the range of valuable species beyond their native habitat. Two diametrically opposed theories have been developed. A particular impetus was given to this discussion by the appearance of Dr. Heinrich Mayr's monumental work on Silviculture. Mayr radically differs from the majority of foresters on the question of acclimatization, on the ability of trees to transmit certain characteristics acquired under new climatic and soil conditions, and on the importance of the source of seed for forestation purposes.

He denies the possibility of acclimatizing or adapting a species to new conditions, claiming that each species can exist only under certain climatic conditions. If a species is introduced into a new environment, in which it meets unaccustomed conditions, it perishes. Mayr further claims that acclimatization of forest trees, if such exist at all, requires such a long time that it has no practical value for man. He also denies the possibility of hereditary transmission of various deviations from the mother type, believing that only the typical characteristics are transmitted and not the various deviations from those caused by changes in environment. He maintains that the deviations from the type are of accidental nature, and, therefore, are not permanent. For this reason he holds that the question of the source of seed has no significance whatever for the forester; that no matter from what locality or from what trees the seed is collected, the progeny resulting from the seed will possess only the characteristics which are typical for the species as a whole.

Mayr is doubtless right in denying the possibility of a tree transmitting qualities which result from soil conditions or silvicultural treatment, but this is about as far as one can go with him. Trees have characteristics which are the result of climatic conditions and these characters are retained and transmitted through inheritance. For instance, the form of Scotch pine in the Baltic provinces invariably has straighter trunks and yields woods of better quality than the Scotch pine of central Germany.

Vilmorin in the twenties and thirties of the last century experimented with growing Scotch pine from German, French, and Russian seed. The pine of the Baltic provinces differed from the rest in that it had a straight, cylindrical, well-developed trunk; and the seed from the plantations of the Riga variety of Scotch pine produced a progeny possessing the same good qualities as the first generation.

Von Sievers in the fifties of the last century made similar experiments in some of the Baltic provinces. The pines grown from seed collected in Darmstadt did not possess such straight trunks as the pines from the native seed. The same experiments were repeated by several other investigators and with the same results.

Cieslar in Austria and Engler in Switzerland have both demonstrated the importance of the source of seed upon the character of the resulting stock. Seed was collected from trees of different species grown in the valleys and in the mountains and were sown under identical climatic and soil conditions, in order to determine whether the characteristics of the mother trees would be retained in the plantations made under exactly the same conditions. It was found that the spruce of the mountains, which grows slower than the spruce of the valleys, retains this characteristic when planted in the valleys and vice versa; other characteristics such as the length of the vegetative activity were also found to be retained. Engler, on the basis of his experiments, came to a diametrically opposite conclusion from that reached by Mayr, namely, that for the planting native or naturalized species seed must be collected in the region in which the trees are to be grown, or at least from localities which are climatically very similar to those in which they are to be planted. Mayr, on the other hand, without really disapproving Vilmorin's, Engler's, and Cieslar's experiments, cites his own experiments which tend to show that only typical characteristics are transmitted and not deviations from the type due to changed climatic conditions. This divergence of opinion as to what characteristics are transmitted through inheritance shows that the question does not permit of sweeping general conclusions.

Engler further points out that the acquirement and transmission of new characteristics to future generations does not require such an infinitely long time as is claimed by Mayr. He says that after the retreat of the glacier into the mountains spruce was one of the first species to reappear in the Swiss valley, the climate of which at that time closely resembled the climate of the higher altitudes. Later, when the climate of the valley became warmer and conditions there became favorable for the growth of hardwoods, the latter crowded out

spruce into the mountains. In the historic epoch, when the forests in the valleys were badly cut and abused, spruce descended again from the mountains into the valley. With the aid of material which was found in excavations, it was possible to determine that spruce was not present in the valley during the neolithic time, and that it appeared only in the helvetic period, that is, early in the middle ages. This, according to Engler, shows that it did not take such a long time for the spruce to acquire the biological characteristics which enabled it to grow in the valley.

This committee, therefore, firmly believes in the importance of the source of seed and in the extension of the range of valuable species as the most immediate possible means of adding to or of enriching our different regions and thus increasing the productivity of our forests.

FOREST SEED COLLECTION TO GAIN THE BENEFITS OF ENVIRONMENT

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The collection of forest seeds in Europe has been an important commercial business for a hundred years or more. In this country seed collection has been practiced for thirty or forty years, but the work had never been systematized until the Forest Service began planting on the National Forests. William T. Cox states on page 18 of Forest Service Bulletin 98 that during the autumn of 1910 the Forest Service collected 107,780 pounds of native seed. This large quantity was not sufficient for the needs of the government since 54,100 pounds of European seeds were purchased in addition to the native collection. This probably represents an expenditure of more than $200,000 per annum by the Forest Service. That the collection of this vast quantity of seed should be done in such a manner as to secure the very best quality in each individual species is a self-evident truth.

It is proposed by the writer to point out in the following paragraphs some of the desirable effects of environment, the benefits of which may be gained by a proper regulation of forest seed collection. Prof. Charles S. Sargent observed thirty years ago in his ninth volume of the Tenth Census that the heaviest specimens of wood of a species usually grow in the southern part of its region of distribution. It

has also been repeatedly demonstrated that the strength of wood of the same structure increased with its specific gravity. If strength is a quality that is transmissible by heredity, then it would seem desirable to collect forest seeds for planting from the most southern region of the distribution of a species. Of course the collector must pay attention to frost resistance. Seed collected from the extreme southern range of a plant might produce seedlings that could not resist cold. If the species belongs to the Rocky Mountain region, there is not much danger from this cause because untimely frosts are about as common in the southern Rockies as in the northern.

Prompt germination is a very desirable quality in forest seeds. Mr. Cox has shown that the seed of *Pinus ponderosa* germinates most promptly when obtained from the eastern foot of the Rocky Mountains and germinates more slowly on proceeding westward to the Pacific Coast. The eastern type of this valuable pine is also very drouth resistant. Since planting on the National Forests is likely to be limited to those areas which because of inhospitable conditions cannot easily be restocked by natural seeding, the seed collectors should secure seed from those regions where the species is subjected to the most trying climatic conditions. It would seem by these facts that western yellow pine seed for reforestation purposes into the National Forests possesses the greatest qualities of hardiness when collected from the Black Hills and southward to the Mexican boundary.

Douglas Spruce is another very desirable western conifer that promises to reward the planter with good returns. Two types of this species are recognized, one common west of the Cascade and Sierra Nevada Mountains and the other scattered through the Rocky Mountains from Canada to Mexico. The wood of the former type is superior to that of the Rocky Mountain type, and for that reason seeds should be gathered from the superior type for planting in regions where abundant moisture is present. No doubt there are thousands of acres in the Rockies that are almost as well suited for the growth of the western type as is the Puget Sound country. The boundaries of such isolated tracts can be determined only by the industrious use of the rain gauge and the thermometer. As soon as such determinations have been accurately made, the planting of Douglas spruce seed from the western coast should be limited in the Rocky Mountain region to the most favorable localities and should be pushed forward as speedily as possible in these localities. Meanwhile, seed collectors in the Rocky Mountain regions have an excellent opportunity to get seed from the eastern type of the species in regions where

environment has compelled the trees to develop habits of drouth resistance and frost hardiness. It seems to the writer that the eastern type of Douglas fir is adapted to a much wider range of planting than the western. Together with western yellow pine, the Douglas fir is probably destined to be used very extensively by the government in reforestation of the denuded portions of the National Forests.

A recent bulletin from the Forest Service on chaparral conveys the impression that our native forest trees cannot be successfully made to replace the chaparral, but suggests the probable suitability of certain hardy species of Eucalyptus for this purpose. Here is a field for the experimenter. If species of Eucalyptus from regions of Australia possessing similar environmental conditions to our southern Pacific Coast region can be introduced and made to thrive on the mountain sides where nothing grows at present but the thorny chaparral, more than five million acres of what is now barren land can be reclaimed in the state of California alone. Our past importations of Eucalyptus have been of the more tender species which cannot endure the trying environment prevailing in the chaparral regions. Future collectors of foreign seeds should make an effort to bring us the Eucalyptus adapted to the more inhospitable mountain sides.

Forest seed collection and importation should be so regulated that each species and varietal type will reach when planted as nearly as possible the exact site best suited in environment for its thrifty growth. To make this possible the Forest Service will need to collect an enormous amount of data on climatology. Every ranger's station in the National Forests should be equipped with a full set of weather recording instruments. The rangers should be taught and required to use, read and care for these instruments and to record the data so obtained. There is such great variation in climate over small distances in mountain regions, that it will be impossible for us to know the possibilities and limitations of our different National Forests until such records have been kept for several years. Each ranger's station should also be a place for the testing of all sorts of new plants that may have promise of usefulness in the immediate vicinity. When the climatic averages and extremes are known for every ranger's district on the National Forests, the seeds collected in each locality can be used with a great deal more certainty of successful results from planting than prevails to-day.

It will then be possible to subdivide our country into seed collector's units each possessing its own peculiar climate and favoring the

growth of its own particular list of species. Nature has already set more or less definite limits about the collection of many of our species by her method of distributing the plants over our country, but man may often be able to extend the region of natural distribution of a species much to his own advantage. For instance Michigan, Wisconsin, and Minnesota would naturally be chosen as the regions in which to collect the seeds of White, Red, and Jack pines, but no one can tell today just how far those species may be safely planted outside of the region of the Great Lakes. Demonstration plantations of course would settle this question after many years of tedious waiting but such plantations are very costly. Systematic weather records together with soil studies would probably solve this problem much quicker than it could be solved by experimental planting alone.

The identification of the life zones and of their subdivisions is another aid that can be brought to the seed collector and seed distributor. The Bureau of the Biological Survey has done admirable work along these lines for the aid of agriculture, but it seems to the writer that the Forest Service might profitably devote more attention to this phase of scientific work. The ability to judge of environmental conditions by correlating the various types of life in a region is fully as desirable for the proper estimation of forest potentiality as is the knowledge of climate.

In conclusion I wish to say that by the study of the climatology and distribution of life in our different forest regions, forest seed may be collected very much more intelligently and its distribution to planters may be regulated in such a manner as to secure very much more effective results than can be secured by haphazard methods of collection.

AN EXPERIMENT ON THE METHOD OF CONDUCTING PLOT TESTS

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The difficulty of obtaining reliable results in the ordinary plot test is familiar to all who have had to do with grain breeding. The factors involved are numerous and complex making the problem one that can be solved only by their separate study with many experiments repeated under diverse conditions.

It is obvious that of foremost importance in the perfect plot test is the reliability of the check used for comparison. In this connection the question has been proposed as to the best kind of seed to use in the checks, whether (1) an ordinary variety, which is usually a mixture of good and poor strains, (2) a pure strain, or (3) a composite of selected pure strains.

This question has recently been raised by Lyon in connection with corn tests and he reports in volume 2 of the American Agronomy Society an experiment in which he compares the uniformity of plots planted from the same ears of corn with others planted from mixed seed. He found that the plots planted from the same ears were slightly more uniform than the others, although the difference was not great enough to be significant.

As additional data bearing upon this point, the result of the following experiment with small grain is presented. The crop used in this case was oats. In the spring of 1911, a plot of ground about 130 feet by 12½ feet was put into oats. This land, a brown silt loam is very level and uniform in appearance. It was planted in rows 8 inches apart with one kernel in a place, the kernels being 3 inches apart and 50 of them in a row. There were 172 rows in the plot, the odd row numbers being planted with a variety known as Silver Mine, one of the best yielding varieties in this locality, and the even numbers with a pure strain which had been isolated from the Silver Mine foundation stock. Thus the rows of the pure strain and of the foundation stock alternated throughout the plot. It must be understood that these were not head-rows, but were planted from composite seed thoroughly mixed so as to be as nearly homogeneous as possible.

By taking special precautions to secure uniformity in planting exceptionally good stands resulted. And here is an important point, for unless the stands of rows being tested are nearly the same, or are at least known, so that allowance can be made for them, no just comparisons can be made.

The rows were harvested separately and the yield of grain in each was determined. A study of the data reveals considerable variation. In the 85 rows from "composite seed" fluctuations in yield from 182 grams to 100 grams were found, while two rows only 16 inches apart yielded in one case 163 grams and 120 grams, respectively. The standard deviation which measures the variability of the entire 85 rows was 18.98 ± 0.98.

In the 87 rows from "pure strain" seed the yields ranged from 125 to 207 grams, and in one case two rows 16 inches apart gave 200 grams

and 134 grams, respectively. The standard deviation for these 87 rows is 22.27 ± 1.13.

These fluctuations supposedly due entirely to soil variations illustrate some of the difficulties encountered in conducting a plot row test.

It might be supposed if soil and other environmental conditions could be made exactly uniform, that rows planted from a perfectly homogeneous lot of seed would yield the same. If this were true, we should expect that two curves representing the yields of the rows of mixed seed and of the pure strain would rise and fall together, giving a picture of the relative productiveness of the soil. In many places this is the case, but in other sections of the plot the lines diverge rather widely, leaving us in doubt as to the soil conditions at those places. Morgan[a] reports a difference in relative productiveness of various plots, as indicated by two different crops, namely, wheat and fodder-corn, grown successively upon the same land the same year. But in our own experiment 2 strains of the same grain growing at the same time showed this same sort of a difference. One explanation of this might be made by assuming that this pure strain of oats possesses a sensitiveness to certain soil conditions and an individuality which is not possessed by the mixed seed, due to its composite nature.

The question as to whether the pure strain of oats gave more uniform yields than the mixed seed is best answered by a knowledge of the variabilities of the two populations, as found by the statistical method. The detailed data show that, while these rather wide individual fluctuations occur, there is no regular or progressive change in the fertility of the soil, and that the average of a number of rows taken from any section of the plot will not be very different from any other such average. It is allowable then to treat each series as a unit and to calculate its variability as a whole, considering each of the two populations independently. The following constants were determined:

Name of variety.	Mean.	Standard deviation.	Coefficient of variability.
Pedigreed Strain.........	171.43 ± 1.61	22.27 ± 1.13	0.127
Silver Mine...............	143.24 ± 1.39	18.98 ± 0.98	0.132

The difference between the standard deviations is 3.29, the variability being the greater in the pure strain, but considering the proba-

[a]Proc. Amer. Soc. Agron., vol. 1, p. 60.

ble errors this difference is not large enough to be significant. If however, we consider the coefficients of variability which take into account the means, the mixed seed appears to be slightly the more variable of the two, but again the difference is not large enough to be significant. These results are in accord with those obtained by Lyon in his experiments with corn mentioned above.

It is of interest incidentally to notice that the data show a very considerable increase in productiveness in the pure strain over the variety from which it originated. The mean of the pure strain, as determined by the statistical method is 171.43 ± 1.61, and of the mixed seed is 143.24 ± 1.39. The difference in means is 28.2 grams or about 20 per cent. Taking into account the probable errors, this difference is large enough to be significant, so that there is practical certainty that if this experiment were repeated the pure strain would outyield the other.

It might be suggested that the system of planting as used in this experiment, in which the tested variety is carefully planted by hand in rows alternating with those of the check seed, would be more satisfactory and reliable than the usual method of making a variety test. Its chief advantages are that errors due to soil differences are so largely eliminated. In this way the advantage is secured of having the plot large enough to include more or less diversity of soil without the errors involved in a plot of the same size conducted in the usual way. A difficulty in the method is found in the element of competition introduced which might give to one or another of the varieties under test an unfair advantage due to some varietal peculiarity. Another objection is the amount of labor involved.

SEED TYPES IN FORAGE PLANTS

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It is a common belief among seedsmen, that the variation in red clover seed as to color is due to different degrees of maturity, different climatic and ecological conditions, etc., and that seeds of different color can be found in any individual plant, even in the same head. Yellow or bright colored seeds are thus regarded as representing an early or, at any rate incomplete stage of development, while dark colored seeds are regarded as having reached their full maturity. The practical outcome of this opinion is that dark-colored clover seed is

always preferred by seedsmen to lighter, as such seed is thought to be of higher quality and to give better returns than the latter.

It is also generally believed, that the size of the red clover seed depends, to a very great extent, upon external conditions, with the result that a certain sample of seed can give rise to a crop of large seeded clover or small seeded clover, depending upon the soil conditions, general climatic conditions in different districts or upon different seasons in the same place.

There is no doubt that this is correct so far as the average size of seed from different districts or different seasons is concerned, just as pure-bred varieties of oats and other cereals can show considerable variation as to size and weight, if grown under different conditions. The average size of the seed in a given clover plant may be influenced, to a certain extent, by the amount of food available to the plant in question. The existence of larger and smaller seeds in the same head may be explained by the amount of nourishment furnished to each individual seed, or by the age or stage of its development as compared with that of other seeds in the head. Such phenomena might be regarded as the result of a sort of environmental correlation or of physiological processes and might be of the greatest interest from a practical standpoint. From a breeding standpoint this kind of variation is however of rather subordinate significance.

This paper shall deal with the "individual variation" of seed within red clover, alsike and timothy, that is with differences *between* different individual plants and not with gradations in the seed *within* a given plant. This explanation presupposes that different individual plants may possess different types of seed, a fact which this paper seeks to substantiate.

RED CLOVER

Color of seed.—A commercial sample of red clover seed shows as a rule a very great variation as to the color of the individual seeds, some seeds being uniform in color, others being variegated, usually with a marked polarity as to the distribution of the different colors. In practically every commercial sample seeds can be picked out which vary from pure yellow to purple, deep violet, or almost black, with all kinds of intermediates and combinations. In some samples, Chilian Red Clover for instance, the brighter colors seem to prevail, while in other samples, such as certain local Canadian varieties, the dark shades predominate.

There is no doubt that small differences in shade may be due to

different stages of ripening. Martinet[a] found that in 23 plants out of 73, all of which bore many heads in different stages of ripening, those heads which were older and consequently contained a larger proportion of ripe seeds, had seeds of a darker shade than those heads which were not so far advanced. This change in color during the later stages of maturity was not, however, characteristic for all 73 clover plants. Among these Martinet found 7 plants which revealed the surprising fact that the most mature heads contained seeds which were actually lighter in color than were the seeds in heads not fully mature, while in the remaining 43 plants no difference in color could be observed between seed from heads at different stages of development. It might be concluded from those results of Martinet's, that even if red clover seed in some instances colors up during the ripening period, this is by no means always the case. To conclude, from the above mentioned results, that in a commercial sample, where all kinds of shades and colors are to be found, the brighter colored constituents represent undeveloped or not fully mature seed, would certainly not be safe.

The real nature of the variations in color as found in commercial samples of clover seed is revealed only by harvesting the seeds from each individual plant separately. A careful examination of the seed from single plants shows without any doubt, that *all the seeds in a given plant are of a certain general color.*

The earliest record on the uniformity in the color of seed within a given plant seems to be the statement of Scribaux[b] that "Les semences d'un même individu présentent une uniformité presque complète," although "les graines mûrissant les premières, ou, ce qui revient au même, les graines les plus grosses sont d'une nuance plus foncée." The universality of the first part of this statement has later been confirmed by Fruwirth[c] and Martinet.[d]

The author collected, during the past summer, seed from about 250 individual plants of red clover, the majority of which were growing in British Columbia and western Quebec. In all cases the seed from each individual plant was found to be perfectly uniform as to the general type of color, although slight modifications in shade were frequently but not always present. Although in these investigations no special attention was paid to possible differences in the color of

[a] Annuaire agricole de la Suisse, 1901.
[b] Journal d'Agriculture pratique, 1896.
[c] Zeitschrift für das landwirtschaftliche Versuchswesen in Oesterreich, 1901.
[d] l. c., 1901.

seeds from heads *at a different stage of development* it might be safely stated that in many cases it is not possible to detect any difference in shade between seeds from such heads. This is especially the case in such plants as have entirely yellow or entirely purple or violet seed, whereas differences in shade are more often marked in seeds of more than one color. Even if those gradations in color really exist, they do not affect the above statement, that all seeds in a given plant have a certain type of color. Among the 250 types of clover seed collected during the past summer, at least 100 types, which are distinct as to color only, can easily be picked out. For reasons which will be quite clear to scientific men at least, the number of color types is practically unlimited.

Shape of seed.—What has been said about the uniformity in color within single individuals can also be applied to the general shape of seeds, this being also surprisingly uniform within a given plant. Thus, some red clover plants have almost spherical seeds, while others have narrow, oblong seeds; some have elliptical seeds, others triangular; some have very fine looking, plump and well filled seeds, while others have seeds which are flattened and rather inferior in appearance.

Weight of seed.—The average weight of a given number of seeds from different individuals is also exceedingly variable. One hundred seeds were weighed from each of 250 individual plants, 92 of which came from the western parts of the Province of Quebec and 158 from different places in British Columbia. The average weight of 100 seeds from each of the 250 individual plants has been found to be 170.76 mg. The average weight of the seeds from British Columbia was found to be 175.22 mg. while that of the seeds collected in eastern Canada was only 163.11 mg. or 12.11 mg. less. To conclude from the facts given, that climatic conditions may influence the weight of seed, and that British Columbia should therefore be able to produce heavier seed than can the Province of Quebec, might however, be misleading. In proof of this it need only be stated that the average weight of 100 seeds from 18 plants collected at a single point in Quebec, namely at Macdonald College, has been found to be 172.7 mg. i.e., 1.94 mg. higher than the average for British Columbia.

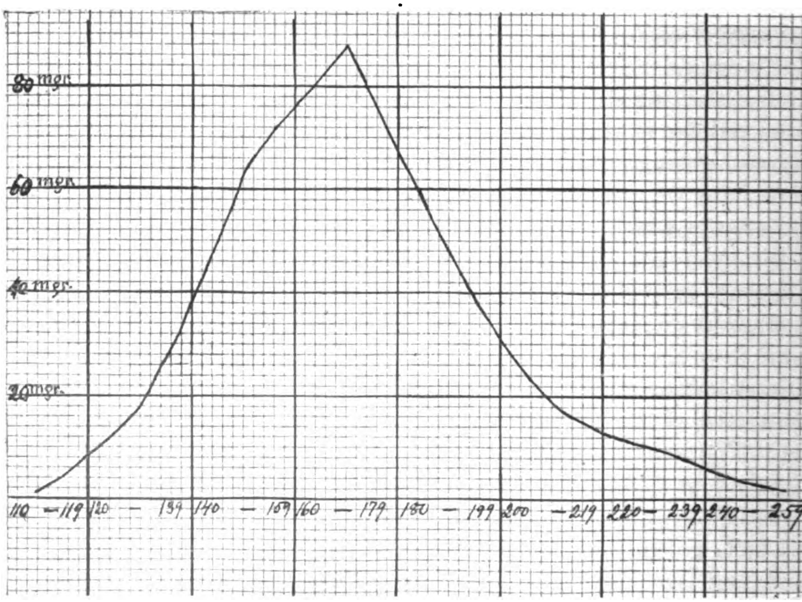
Erikson[e] has found that the weight of 100 seeds can vary from 150 to 260 mg. in different plants, the range of variation thus being 110 mg. In the 250 samples collected by the author last summer, the variation extends from 118 to 252 mg. for 100 seeds, the range of

[e] Svensk Klover-och Timotejfroodling (The Growing of Clover and Timothy in Sweden), Norrkoping, 1910.

variation thus being 134 mg. The distribution of the different types into different weight classes, each with a range of 10 mg., will be seen from the following figures:

110 to 119	120 to 129	130 to 139	140 to 149	150 to 159	160 to 169	170 to 179	180 to 189	190 to 199	200 to 209	210 to 219	220 to 229	230 to 239	240 to 249	250 to 259
1	5	13	24	39	49	39	27	21	10	9	9	1	2	1

It must be pointed out that the material available is too small to allow any safe conclusions as to the real nature and extent of the



CURVE ILLUSTRATING THE INDIVIDUAL VARIATION IN THE 100-SEED WEIGHT.
The number of individuals being rather small, the width of the classes has been made 20 mg.

variation. The present figures projected in the above graph seem however to indicate that the distribution of the different weight types into the different classes is in accord with the law of Quetelet.

Correlations.—A few attempts have been made to find some kind of correlation between the color and the weight of the seeds. Thus Haberlandt[f] picked out 100 differently colored seeds from commercial

[f] Oesterreichisches landwirthschaftliches Wochenblatt, 1879, No. 2.

samples. He gives the following average weight of 100 seeds, one year old:

	Gram		Gram
Yellow	0.1834	Grayish green	0.1794
Violet	0.1813	Brown	0.1704

As a result of his investigations he came to the conclusion that the yellow and violet seeds are the heaviest in the order given. These results of Haberlandt's are quite contrary to those obtained by Preyer[8] who has found the following weight for 100 seeds:

	No. 1	No. 2	No. 3
Yellow	0.1676	0.1756	0.1656
Violet	0.1755	0.1825	0.1831

Thus the results obtained by Preyer seem to indicate that the violet seeds are the heaviest. How is this contradiction in the results obtained by Haberlandt and Preyer to be explained?

From the 250 samples collected last summer, 39 samples which were either entirely yellow or almost yellow were picked out at random. The average weight of 100 seeds of those 39 samples was found to be 166.23 mg. Of the darkest colored samples there were also picked out 39 samples, at random, 100 seeds of which were found to weigh 167.23 mg. This means that the difference between the average weight of yellow and very dark colored being only 1 mg. there does not seem to exist any correlation between the color and the weight of the seeds. That this really is the fact can be clearly demonstrated, if, instead of basing the conclusion upon the average weight, we study the weight of the seeds from each single individual. The following table shows the distribution of the above mentioned 39 samples of yellow and of dark colored seed into the different weight classes. It shows beyond contradiction, that *the weight of the seed varies independently of the color, i.e., that there does not exist any correlation between color and weight.*

	110 to 119	120 to 129	130 to 139	140 to 149	150 to 159	160 to 169	170 to 179	180 to 189	190 to 199	200 to 209	210 to 219	220 to 229	230 to 239	240 to 249	250 to 259
Yellow	......	1	1	5	7	12	5	4	2	......	1	......	......	1	....
Dark	......	1	5	6	5	5	4	5	2	2	......	4	......	......	....

[8] Ueber die Farbenvariationen der Samen einiger *Trifolium-arten*. Berlin, 1899.

Dark seed as well as bright seed may therefore be heavy or light, or vice versa, their weight being in no way associated with their particular color. It is a well known fact, that in some commercial red clover samples the dark seeded biotypes prevail, while in others the light colored types are most common. If, therefore, heavy, yellow-seeded types should happen to predominate in one sample while in another sample heavy dark seeded types prevail, it is easy to understand why the yellow colored seeds may sometimes seem to have a higher average weight, while in other cases exactly the reverse seems to be the case.

A statement of Martinet[h] that "une variation du trèfle cultivé à fleurs blanches, récoltée en capitules par M. A. Jordan, à Carouge (Jorat), nous a donné les graines absolument jaunes, sans autre nuance quelconque" might indicate that white colored flowers are associated with yellow colored seed. This, however, is not the case, as all the yellow seeded types observed last summer have typical purple flowers.

ALSIKE CLOVER

What has been said regarding the uniformity of the seed as to color, shape and size within individual plants of red clover is also applicable to alsike. As regards color, the seeds of a given alsike plant may be entirely black, while in another individual they may be quite greenish. I cannot discuss here the question as to what extent the mixed appearance of a commercial sample of alsike seed is due to the seeds being in different stages of development. The existence of distinct seed types seems, however, to indicate that it is chiefly due to the fact that in an ordinary commercial sample, many biotypes, different as to color, size and shape, are mixed. Although samples of only about 25 seed types have been secured by the writer, great differences have been found in the relative weight of the different types. Thus 100 seeds from one plant were found to weigh 60 mg. while 100 seeds of another plant weighed 80 mg., i.e., 33 per cent more. The material available at present is, however, much too small to be used as a basis for definite conclusions as to the range of variation and other phenomena connected with the seed.

TIMOTHY

Individual variation in timothy seed has been especially studied in plants, growing in the neighborhood of Edmonton, Alta. When visit-

[h] l. c., 1901.

ing this place during the past summer, the writer came upon a railway cutting where thousands of timothy plants were growing together, evidently from seed dropped from passing trains. From individual plants, which differed from each other in the most astonishing ways, there were collected about 450 samples of seed.

The study of the individual variation of this timothy seed reveals many interesting things. Scores of very distinct seed types, every one uniform, within each individual plant, can easily be distinguished. It would be of very little advantage to describe those different types. It may be sufficient to state that all kinds of types exist between long, narrow-pointed types and short, plump, almost spherical ones; that some plants have seeds which are twice as large as the seeds of others; that some types are very dark dull colored, others shiny and bright.

It must be mentioned especially that the plants collected were growing under practically the very same conditions in the same kind of soil, and that any influence of different weather conditions during the ripening period on the differentiation of the seed types is out of question. Thus, when two seed types, extreme as to size, are found in plants growing side by side, or when dark colored seed occurs in plants growing cheek by jowl with bright colored ones, there can be little doubt, that the individual variation of the seed is quite independent of external conditions. The differences as to shape, color and size between the seed of different plants must have their foundation in the very morphology of the plant. They must be characters of constitutional quality, characters which form an essential part of that biological unity called biotype.

The comparison between the vegetative characters of plants and the type of seed, seems to indicate that the seed type of the plant is independent of its other peculiarities. It is true that first class seed has been collected from plants which were quite superior from fodder standpoint, but it is equally true that excellent seed has been gathered from plants which were vegetatively poor. This lack of correlation between apparent value of seed and value of the vegetative parts in timothy is quite in accordance with the facts revealed from experiments with red clover at the Experiment Station of Rhode Island, namely, that there is no connection between a given color of red clover seed and the amount of nitrogen in plants produced from seeds of that color.[1]

[1] Report of the Horticultural Division of the Rhode Island Agr. Exp. Sta., 1906–07, part 2.

From a practical point of view this lack of correlation is of special interest. It simply means that it is not possible to judge the quality and value of the plants from the quality of the seed they produce. This might seem very discouraging at first glance, but as a matter of fact it is really quite the contrary. Thus it must serve to induce the plant breeder to produce strains which are not only of superior quality, but which can also easily be checked by means of distinct morphological characters possessed by their seed.

The possibility of fixing the different seed characters by breeding.—It is evident that only conclusions of probability as to the hereditary quality of the different seed characters can be made from the observations of the past summer on the said seed types. Whether or not such characters as color, shape, etc., can be hereditarily transmitted to the progeny, is a question that can be solved only by direct experiments. Very few experiments in the said respect have been carried out up to the present time. Martinet[k] has made a few observations which seem to indicate that the color of clover seed is a hereditary unit. He concludes: "Dans douze plantes egrenées en 1900, 9 ont reproduit des graines de même nuance et 3 seulement des graines de coloration mixte; sur les 26 plantes observées en 1902, 23 présentent une coloration des graines semblable à la plante mère, tandis que 3 plantes seulement ont donné des graines d'une autre nuance."

The practical meaning of these observations of Martinet's is likely that it might be possible to produce, by proper breeding, varieties of clover with a special color of seed, and there is very little doubt that it will also be possible to fix the other seed characters by breeding so as to obtain strains having a certain distinct type of seed.

THE ORIGIN OF AN EARLY VARIETY OF MATTHIOLA BY MUTATION

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Two problems, primarily, interest the breeder of plants or animals. One, that of the transmission of characters, is far on the way to solution in detail, a solution at least proximate and practically usable. The other, that of the origin of new characteristics, has been restated for us by Mendelism and the related theories, which have sharply challenged the old hypothesis of gradual hereditary change.

[k] Annuaire agricole de la Suisse, 1903.

Only extended experimentation under carefully controlled conditions can with reasonable certainty prove or disprove the absolute stability of genotypes in the absence of crossing. Mutation, or the apparent sudden origin of new genotypes, is plainly a widespread phenomenon, but its significance, especially in relation to "progressive" variation, is still in question. The mutative origin of types showing normal development and vigor, and the behavior of these types when crossed with the parental form, are matters of especial interest.

It is probably easy to attach too much importance to the appearance of "degenerate" mutants. If mutation consists of a qualitative change in a definite hereditary substance, it is to be expected that the resulting form will often be biologically inferior, under certain conditions or under any possible conditions, to the parental form. We should consider it probable that many such changes even produce non-viable gametes or zygotes, i.e., types of gametic constitution that either preclude any formation of zygotes or insure early cessation of development through lack of adjustment to the conditions of life. Bateson and Saunders suggested[a] in 1902 that there may be biotypes incapable of development to maturity as homozygotes, and the prediction has been verified in the case of certain chlorotic forms. We are not yet justified in assuming that the general nature of the unknown mutative process in such cases differs from that which prevails where "normal" biotypes result.

Further, if a mutant form differs only slightly from the parental type, the occurrence of the mutation may defy detection by the most refined and laborious methods. Some bizarre mutants are to be expected, and these are readily found, while "normal" mutants, if they occur, must often fail of detection.

The evidence tends more and more to prove that there is genetic continuity of the chromosomes, and that a full haploid complement of chromosomes is necessary to development. Further, a mutant type and its parent form, and related forms in general, commonly agree in their number of chromosomes. All this tends to make it more probable that mutation usually, at least, depends upon a change in the nature of an essential substance or substances, perhaps in the essential constitution of one or more chromosomes, rather than upon mere physical abnormalities in mitosis.

In the writer's cultures of ten-weeks stock (Matthiola), a remarkable series of variant types has appeared. Some of these forms have

[a] Evol. Com. Roy. Soc., Report 1, p. 133.

occurred repeatedly among the progeny of ordinary plants, and in several lines of descent, always in very small numbers. Four at least of these forms definitely transmit the new character to part of their progeny, the rest of their progeny conforming to the usual type of the variety. Apparently the mutating germ-cell usually meets a normal one, forming a heterozygote, and segregation takes place when this hybrid mutant forms its gametes.

The extracted "normals" are evidently pure, but in three cases out of the four the dominant mutant type falls far short, in unselected cultures, of the expected 75 per cent, and pure dominants are rare or absent. In one case there is apparently partial gametic coupling with singleness and doubleness, which would partially explain the deficiency; in one case *two* new factors are perhaps concerned, but usually with a great excess of normals; in a third case, there may be simply severe selective elimination of the weak-growing mutant type during embryonic development.

In the remaining case, of the four mentioned, the second generation indicates that the plants of the first generation were the progeny of a monohybrid, with an approximation to the ordinary ratio. The original mutant, an early dwarf plant, is WG9–C10 of Chart 1 in the writer's paper in A. B. A. Report 6, which shows that the progeny of this plant had a lower average number of main-stem internodes than the progeny of any other parent tested. Means for time of flowering show a similar though less marked tendency to earliness. The real condition of the progeny of the mutant, however, is shown much better by the actual frequency-distributions for number of internodes and time of flowering, as presented in tables 1 and 2 herewith. Part of the progeny are early, with few nodes, and part are ordinary. The variability is evidently greatly increased, and the distribution plainly suggests that WG9–C10 was a monohybrid, the ordinary type of the variety being recessive.

All the singles of this generation were tested in 1910–11, in comparison with plants of the same and another line but of ordinary ancestry, and apparently conclusive evidence was obtained that WG9–C10 was a monohybrid, earliness (and the correlated few-nodedness) being definitely and perhaps almost completely dominant. Fifteen-seed cultures from selected parents, with germination usually perfect,[b] were grown in the greenhouse under fairly uniform conditions,

[b] Because of lack of space, one plant of each lot was not repotted, and is not included here. The results, however, are not prejudiced, since the plants were selected by number; No. 5 or No. 10, whichever was at the back of the bench in the rows of 10 pots each, was always omitted.

TABLE 1.—*Matthiola, 1908–09. Frequency distributions for number of internodes below first flower.*[1]

	Singles.						Doubles.					
	House C.		House M.		House W.		House C.		House M.		House W.	
P_1	WG9–C10.	Rest.	WG9–C10.	Rest.	WG9-C10.	Rest.	WG9–C10.	Rest.	WG9–C10.	Rest.	WG9–C10.	Rest.
Internodes												
16	1											
17												
18												
19	1											
20	1						1					
21			2									
22			1				1		1			
23									1			
24								9				
25	1	2	1	1			2	25				
26								29		1		
27	1	7		1			1	22		2		
28		17						6		9	1	
29		24		1						14		
30		13		1				1	2	22		1
31		8		2						27		
32		2		7						5		
33		1		15	1					3		
34			1	16						4		1
35		2		19	1							5
36				4	1					1		6
37				1	1							8
38				8								5
39				3								13
40				1								6
41			1	1								8
42		1			1							6
43						1						12
44												9
45					1							6
46						4						3
47						3						3
48						4						
49					1	3						1
50						6						
51					1	3						2
52						10						1
53						6						
54						2						2
55					1	3						
56						7						1
57						8						
58						1						
59						1						1
60						3						
61												
62						1						

[1] The distributions given in tables 1 and 2 are those from which were calculated part of the statistical constants presented in the writer's paper in A. B. A. Report No. 6, except that the progeny of WG9–C10 are here given separately from the rest. The letter "G" in "WG9" refers to a soil factor in the first year's cultures.

TABLE 2.—*Matthiola, 1908–09. Frequency distributions for number of days to flowering.*[1]

	Singles.						Doubles.					
	House C.		House M.		House W.		House C.		House M.		House W.	
P_1........	WG9-C10.	Rest.	WG9-C10.	Rest.	WG9-C10.	Rest.	WG9-C10.	Rest.	WG9-C10.	Rest.	WG9-C10.	Rest.
Days.[2]												
110			1									
111			1									
112												
113												
114												
115												
116				1					1			
117					1							
118			1	2								
119				3								
120	1			4								
121			1	2						1		1
122				3								2
123				8	1				1	1		2
124			1	4						1		2
125				7	1					5	1	3
126				16						7		7
127				3	1	2				9		2
128				4		3				8		5
129				7	1	4				8		7
130				1	1	3				12		4
131		1		2		4			2	12		3
132	1			1		2				7		8
133	1			1	1					4		7
134	1	2		2		1				2		7
135		4		4		4				6		6
136		1	1	1		3	1					4
137		7		2		3		3		1		2
138		10		1		9		4		1		1
139		18		1	1	2		8		1		3
140	1	7		1		4		13				3
141		10				1	1	9		1		3
142		4				6		15		1		1
143		4			1	5	2	10				2
144		4				2		9				2
145						3		6				3
146							1	5				2
147								4				
148						2		1				1
149						2		1				
150		1				1		2				
151		1						1				1
152												2

[1] From time of planting to time of emergence of corolla of earliest flower from calyx. See A. B. A. Report, vol. 6, p. 386. The means given in vol. 6 for time of flowering were calculated from the times of observation (i.e., from the upper class limits), without correction for this fact, and therefore are uniformly too high by one-half day.

[2] To time of observation (upper class limit).

TABLE 2.—Continued.

P₁.........	Singles.						Doubles.					
	House C.		House M.		House W.		House C.		House M.		House W.	
	WG9-C10.	Rest.	WG9-C10.	Rest.	WG9-C10.	Rest.	WG9-C10.	Rest.	WG9-C10.	Rest.	WG9-C10.	Rest.
Days.[1]												
153		1										1
154												
155		1						1				1
156												
157												
158												
159												
160												
161												1
162												
163												
164												
165												
166												
167												1
168												
169												
170												
171												
172												
173		1										

[1] To time of observation (upper class limit).

and larger cultures from all parents in the field. Unfavorable weather conditions made the field results less definite than the others, and incapable of brief presentation; so figures will be given here only for the greenhouse.

The parents (from the mutant line) that were used for the greenhouse were selected as follows. The selection was based on number of internodes, and on earliness also where two plants had the same number of internodes. Three parents were taken for each of the three parental environments (cool, medium temperature, warm = "C," "M," "W," in pedigree numbers)—the plant with most nodes, the one with fewest, and an intermediate one.

Tables 3 and 4 show the frequency-distributions for number of internodes in the progeny-lots and table 5 gives the ordinary statistical constants corresponding to table 3. Plainly the three late or many-noded progeny of the supposed hybrid mutant were pure extracted recessives, and five of the rest were probably heterozygous, while one, WG9-C10-M4, seems to be a pure dominant.

TABLE 3.—*Matthiola, 1910–11. Singles. Frequency distributions for number of internodes below first flower.*[1]

P_3	WG9																				
P_2......	C1		C10			C5		C10			C9		C10			C9		C10	C10		
P_1......	M3	M9	C2	C5	C1	M6	M9	M4	M2	M7	C3	C7	W6	W5	W10	M5	M8	C10	Not Late.	Late.	Late. Late.
Internodes.																					
16														1					1		
17			1	1									1						3		
18			1					2					1	1					5		
19			2	1				2	1				2	2					10		
20			1	1				1					1						4		
21														1	1			1	2	1	
22									1				1					1	3		
23				1									1						2		
24			1					1						1					3		
25									1										1		
26		1							2			1					1		2		3
27							1				1			1			2		1		4
28						2			1		2				1	3	2		1	1	9
29		4	1	1	6	3	2			2	4	3	1		1	2	1		3	9	19
30	1		1			2					2					1	1	1	2		7
31	2	3		2			1			1					2				2	3	6
32	1				1															1	1
33																					
34	1																				1
35	1																				1
36												1									1
37																					
38		1																			1
39																					
40																					
41																					
42																					
43																					
44																					
45																					
46																					
47																					
48																					
49	1			1															1		1

[1] The plants of all progeny-lots reported in tables 3 and 4 stood on the same bench in the greenhouse in the order here given, all lots but the last given constituting together one solid block of plants. Under the grandparent, WG9–C10 (P_2 generation), its early progeny used as parent is always at the left, and its late progeny at the righ in Tables 3 and 4.

In the three columns at the right in tables 3 and 4, the progeny-lots are combined. The correspondence of the distribution of the extracted late or many-noded progeny with that of the lates of ordinary ancestry is surprisingly close, when the smallness of the numbers is considered.

TABLE 4.—*Matthiola, 1910–11. Doubles. Frequency distributions for number of internodes below first flower.*

P_3	WC9																				
P_2	C1		C10		C5			C10			C9		C10			C9		C10	C10		Late. Late.
P_1	M3	M9	C2	C5	C1	M6	M9	M4	M2	M7	C3	C7	W6	W5	W10	M5	M8	C10	Not Late.	Late.	
Internodes.																					
14													1						1		
15														3					3		
16									2					1				1	4		
17								2	2									2	6		
18			1					3					1						5		
19				1				1						1					3		
20														1					1		
21								1								1		3	4		1
22			1	1	1			1	1		1						1	2	6	1	2
23										1				1			1		1	1	1
24			2										1			1			3		1
25	1			2	1		1		1	2	2	1	1		1	2	2	2	6	4	9
26		2			3	2	7		1	1	1	5			3	1	1		1	7	19
27	2	2		1	2	4	1		1	5	1	2			3	3			2	10	15
28	1		1			1													1		2
29	1			1															1		1
30															1					1	
31																					
32	1																				1
33			1																1		
34										1										1	
35																					
36																					
37																					
38																					
39		1					1														2

These very small-scale results are confirmed by study in the field of larger lots, usually of from 70 to 80 plants each, of progeny of all but one of the first-generation singles. The habit of the plants in the field made accurate determination of the number of internodes evidently impracticable, but observation of the time of flowering leads to the conclusion that the following classification of the parents is probably correct:

Class.	Cool house.	Medium house.	Warm house.	Total.
Pure early................	0	3	1	4
Heterozygous............	3	1	5	9
Pure late.................	2	2	3	7

There is practically no doubt about the number of pure late parents, unless possibly one more should be classed here, but there is some uncertainty with reference to the separation of the other two classes.

It is interesting to note that the only apparent mutant, of those so far tested, to give this regular result, is also the only one that seems to differ from the parent variety only in size and earliness; the others differ in leaf-characters, and are usually deficient in vigor. The case is also of special interest as an instance of apparently nearly complete dominance of a size-character, and as showing dominance of dwarfness over tallness.

East[c] reports for Nicotiana, and East and Hayes[c] for maize, that various "abnormal" mutant types have proved dominant to the parental form. The results of the writer are entirely in agreement with these on this point, as no mutant yet tested has proved to be a pure recessive. Possibly the factorial basis is not always simple, if indeed normal segregation occurs at all, but no hypothesis of *absence*

TABLE 5.—*Statistical constants for distributions given in Table 3.*[1]

Parents	n	Mean	Standard deviation	Coefficient of variability
"Pure-bred" late	53	29.434 ± 0.205	2.215 ± 0.145	7.525 ± 0.496
Extracted late	15	29.000 ± 0.417	2.394 ∓ 0.295	8.257 ± 1.024
Early (simplex and duplex)	42	21.929 ± 0.450	4.328 ∓ 0.319	19.738 ± 1.508

[1] Omitting the two variates at 49, and also all the progeny of WG9-C10-C10, which, with part of its progeny, belonged to another "mutant" type as well, and thus might introduce other factors of genetic internode-variation if included.

of factors seems adequate, at least unless absence in *one* gamete profoundly modifies the resulting zygote.

With two or three of these forms, low general vigor, small seed-production, and to some extent poor germination of the seed produced are associated with the aberrant ratios. Perhaps the mutant character is regularly carried by half the gametes but undergoes selective elimination, either while within the ovary or later, because of the low vigor of the mutant form. Field cultures, with a relatively low rate of germination, have given evidence of a high rate of selective elimination of three of these types at or soon after germination. This suggests that the percentage of mutants in the general population may be much below the percentage of mutating gametes.

The early mutant was apparently unique among about 151[d]

[c] Conn. Agr. Exp. Sta. (New Haven) Bulletin 167, p. 135.

[d] One hundred and sixteen of these absolutely unselected, except for the rejection of one diseased plant that probably would have died in any case.

progeny of plant WG9; this fact and the apparently simple (monohybrid) dominant inheritance of the character seem to preclude explanation on the basis of heterozygosis of WG9. The flowers of this plant were not bagged, but the only other single-flowering plants in the same house have given progeny usually normal, and there is no evidence, with the possible exception of the case of one double, that the early character has appeared at all in the cultures aside from WG9–C10 and its progeny. We evidently have a new dominant character arising *de novo*—and this a character of possible practical value, since the new type flowered much more successfully than the parental type during the hot dry summer of 1911.

These results have some bearing on the question of the possible value in breeding of non-economic morphological characters correlated with characters of practical value. The early type differs more decidedly from the ordinary type of the variety in the number of internodes than it does in earliness, and the former feature is, at least with normally developed plants, much the easier to determine with accuracy. A single examination of the mature plants for number of internodes is evidently of more value than flowering data requiring frequent examinations for several weeks.

INHERITANCE OF MAMMAE IN SWINE

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So many theories and misconceptions are prevalent in regard to the inheritance of mammæ in swine, the functioning of the same, and the relation of functional mammæ to the number of pigs, that a careful investigation should prove of lasting benefit. The practical value of the same since the discovery of the effect of ration on functional mammæ is most important.

It has long been believed by most farmers that only as many mammæ function as there are pigs in the litter, and it has also been believed by some that a sow will not have a numerically larger litter than she has nipples. In order to investigate these points, and allied questions, records on 31 gilts with their living pigs were taken. The boar which was the sire of all the litters had 11 nipples, the following pattern being present: the forward pair were located under the last rib, the odd teat was next, then the 4 remaining pairs occurred in normal position. As a matter of interest it may be well to note that in every

individual but 3, the odd nipple, when present, was located just behind the first pair. In these 3 the odd one was so indeterminately placed as to give a triangular effect and the pair was indistinguishable. A correlation table plotted showing the relation of dams and offspring in number of mammae gives the following result:

Mean of dams in relation to pigs..................	11.924	mammae
Mean of pigs....................................	11.121	mammae
Standard deviation of dams......................	0.9478	
Standard deviation of offspring..................	1.1442	
Coefficient of correlation........................	0.0457 ± 0.0478	

This correllation is of no significance since the probable error exceeds the coefficient.

Of the pigs 130 showed a symmetrical pattern in the mammæ and 68 showed an odd number on one side or the other. It is interesting to note that in all but 3 of the cases the extra mamma appears on the left side. Comparison was also made to determine whether symmetry in the mother had anything to do with symmetry in the offspring. Fifteen asymmetrical sows produced 35 asymmetrical and 68 symmetrical pigs. Sixteen symmetrical sows produced 33 asymmetrical and 62 symmetrical pigs. Placed on a percentage bases the asymmetrical pigs from asymmetrical sows was 33.98 per cent and from symmetrical sows was 34.73 per cent. The difference would indicate nothing at the present writing.

TABLE 1.

		Number of pigs.							f
		8	9	10	11	12	13	14	
No. of mammae of sows.	10	....	....	8	5	5	1	....	19
	11	....	....	13	11	12	4	....	40
	12	1	1	25	21	22	5	1	76
	13	1	3	14	14	27	3	1	63
	f	2	4	60	51	66	13	2	

The question as to whether the mammæ pattern showed primary or secondary sexual inheritance was next considered. The boar was taken as the basis and the sexes of pigs possessing the same number of nipples was ascertained. Twenty-six boars and 25 sows showed 11 mammæ each. This was close enough to a strict balance to indicate no influence, yet lest the sows possessing 11 mammæ might partially influence these figures, the pigs from their litters were omitted

from consideration. This gave 19 boars and 21 sows, so that again no influence could be inferred.

Table 2 shows a perhaps useless but nevertheless interesting comparison of the relations of the sow pattern to the pig pattern. Column 1 shows those that resemble the sow in pattern; column 2, the boar; column 3, intermediate between parents; column 4, those which come

TABLE 2.

Number of mammae of sow.	Number of pigs showing pattern—			Symmetrical pattern from asymmetrical, of parents.	Number of pigs unrelated.
	As in sow.	As in boar.	Intermediate.		
12	3	1	0	5	1
10	1	3	0	2	0
13	0	0	1	3	1
10	3	0	0	2	0
12	0	2	0	1	1
11	1	1	0	5	1
11	2	2	0	6	0
13	1	1	4	2	0
11	2	2	0	1	0
12	1	1	0	4	0
11	3	3	0	5	0
11	1	1	0	5	0
13	0	1	4	2	1
13	1	1	6	1	0
13	0	1	5	0	0
11	2	2	0	3	3
12	2	2	0	1	0
12	4	0	0	2	0
12	3	2	0	1	2
12	2	0	0	1	1
13	0	2	3	0	0
10	4	1	0	1	0
12	0	0	0	2	1
12	0	4	0	4	0
12	3	2	0	0	1
12	2	3	0	2	0
10	0	1	0	0	1
12	2	4	0	2	1
13	1	2	2	3	0
13	0	4	1	2	1
13	0	2	1	2	1
Totals..........	44	51	27	70	17
Per cent........	22.22	25.27	13.64	35.45	8.58

under none of the previous headings but represent a symmetrical condition in the pig produced by the loss of the odd nipple or the balancing of this nipple by another, when compared with the pattern of one or the other of the parents.

The table shows that by far the majority of cases come under the fourth class; that is, symmetry from asymmetrical parent. If,

however, this column is considered only from the standpoint of those animals which have added a nipple to produce symmetry only eighteen are left. This gives a per cent of 8.63 and makes the last column the leader with a per cent of 35.4. The first and second columns contain eleven duplicates, owing to the fact that in some cases boar and sow show the same pattern.

If the odd-numbered mammæ represent a tendency to variation from the normal pattern it is interesting to compare whether functional or rudimentary mammae are more variable. Thirty-seven boars show the odd pattern, 64 do not; 31 sows have an odd nipple, 66 do not. This gives a per cent of asymmetrical patterns in rudimentaries of 36.63 per cent and in functional 31.96 per cent. If the dams were considered in these latter figures the per cent in the last figures would be very slightly lowered.

The excess of males with reference to living pigs was 2.02 per cent. This may influence slightly some of the comparisons where sex is considered.

The relation of functional mammæ to total mammæ is of interest if not of importance. Professor Evvard at the Iowa Station has shown (unpublished work) that the mammæ may be stimulated into function by certain rations, and consequently this point loses value from a hereditary consideration. In two sows all mammæ functioned (totals) and the lowest per cent of functional nipples in any sow was 36.36 per cent. This sow had 11 nipples, 4 of them functional, and only 3 pigs.

It is in regard to the relation of functional mammæ and pigs that the most gross misconceptions are extant, and it is to this issue one turns with practical interest. In 30 per cent of the sows the number of teats giving milk and suckling pigs was equal. In 63.34 per cent the milking mammæ exceeded the number of pigs and in 6.66 per cent the pigs exceeded the functional mammæ in number. In the latter class there was one more pig for one sow and an excess of two in the other; in the second class the total number of pigs was 71.51 per cent of the total number of functional mammæ.

Looking at the inheritance from a Mendelian standpoint, Mendelian phenomena of some sort seem suggested when we consider the relation of the animals with an odd number of nipples to those with an even number. The totals with the pigs show 130 pigs with symmetrical mammæ and 68 pigs with asymmetrical mammæ. When divided according to the odd or even number in the parent, the proportion still holds, 35 to 68 in the offspring of asymmetrical sows.

It seems to the writer that there are at least two factors operating and that one of these is rather complex in make-up. The first, and complex perhaps, is the simple addition or substraction of pairs of mammæ from parents to offspring, and secondly a restriction factor which prevents the development of one nipple of the normal pair. A theory might be developed to cover the data on hand, but it would seem preferable to wait until more material is collected.

NUTRITION AS A FACTOR IN FETAL DEVELOPMENT[a]

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There has been much difference of opinion among breeders and feeders as to just what individual influence breeding and feeding has on the development of the animal. Observation and common sense teach us that feeding and breeding go hand in hand, and that to secure ideal development the highest skill in both lines is necessary. The indifferent feeder can in one generation undo, in so far as the development of the individuals of this generation are concerned, all of the wonderful results which the breeder has been many generations in accumulating. While it is true that the abused animals of this generation can hand down their stored up inheritance, yet this misused generation is not without its adverse effects. To breed well and to feed well are the two great essential requisites in the upbuilding of our domestic live stock.

At what period in the life of an individual does the feeder's influence begin? This is a highly important question. Technically speaking the feeder begins his influence even before the hour of successful impregnation. This influence may be small, it is true, but it is nevertheless potent. This is best illustrated in the effect of flushing upon the number of offspring born.

Do the best gainers at breeding time have the most offspring? At the Iowa Station in the fall of 1910 we bred 35 gilts to the same sire. These sows were all gaining at a different rate when impregnation occurred. These gilts were divided into 7 lots with 5 in a lot. The two heaviest gainers in each of the 7 lots (14 sows in all) farrowed on

[a] Work planned and conducted jointly by the author and W. J. Kennedy and John M. Evvard. Animal Husbandry Section Iowa Experiment Station. Read before the American Breeders Association, December, 1911. Dr. A. W. Dox is coöperating in the chemical work.

the average 8.57 pigs. The 2 lightest gainers (14 in all) gave birth to 7.5, while the intermediate sows (7 in all) gave us 7.43. Figured on another basis the three heaviest gaining sows (21 in all) yielded 8.19, while the three lightest (21 in all) blessed us with only 7.47. In this last computation the intermediate sows are counted twice, with both the heaviest and lightest gainers. Studying the matter still further we find that the one heaviest gaining sow at the time of successful impregnation (an average of 7 sows, or one from each of the 7 lots) produced 9 pigs each at birth, while the lightest gainer from each lot (an average of 7), produced only 7.14. True enough these numbers are not large enough to put the final stamp of positiveness upon this influence, but it bears out the practical opinions of the more intelligent swine breeders. Sheep men have for ages believed that the flushing of ewes at breeding time increases the number of offspring. By flushing we mean merely a fairly rapid rise in the plane of nutrition. An ideal physiologically balanced ration with its optimum amount of water, protein, carbohydrates, fat and ash constituents seems to be the successful stimulus.

If it is granted that correct feeding at the proper time will increase the number of offspring, it certainly stands to reason that this optimum nutrition furnishes a more suitable food environment for the ova which are impregnated. "The Effect of Rations Fed Pregnant Gilts upon the Size, Vigor, Condition and Composition of Offspring" was our theme of investigation when we undertook the following described fundamental research. The inquiry really is: "How does the nutrition of the mother affect the fetal growth?" Swine were used in our experiment, and gilts were selected for the work. Gilts are really young, immature, ungrown, prospective, swine mothers. The 35 gilts were divided into 7 lots of 5 each. These swine were all exceptionally high grade or pure bred Duroc Jerseys of our own breeding and raising. They were closely related, for the most part, sisters or half sisters. These young gilts were selected from a very large number of prospective mothers along toward the end of the forage crop season. They were all excellent individuals of good type and at the time the experiment began were in a thrifty growing condition.

The allotment and rations fed:

Lot 1 .... Ear corn alone
Lot 2 .... Ear corn plus meat meal 1/30
Lot 3 .... Ear corn plus meat meal 4/30
Lot 4 .. Ear corn plus ⅓ of a grain mixture of (oats 3, bran 3, middlings 3, oil meal 2)

Lot 5....Shelled corn plus chopped clover—mixed-and-sprinkled with molasses
Lot 6....................................Ear corn plus clover in racks
Lot 7........,...........................Ear corn plus alfalfa in racks

The basal ration is corn, fed in the ear form in all lots excepting lot 5, where it was shelled in order to facilitate mixing with the chopped clover. The corn was of excellent quality. The meat meal is a 60 per cent protein product, and contains in addition to this high amount of nitrogenous matter, practically 10 per cent fat and 14 to 15 per cent of ash, a large proportion of which is tri-calcium phosphate. Ordinary black strap molasses was used. The clover was of fair quality and quite leafy. The alfalfa was choice in grade and of the third and fourth cuttings.

That accurate individual weights upon every gilt in the experiment be recorded, great care was taken to secure three successive daily weighings at the beginning and close of her record. Individual weights were also taken throughout the experiment at intervals of ten or fifteen days, as deemed necessary. The endeavor was to have all of the sows in the various lots gain on the average ½ pound per day throughout the experiment. The feed was so regulated as to secure this gain.

Record of feed eaten and gains made.

Lot number.	Supplement to Corn.	Average initial weight per gilt.	Shelled corned[a] eaten per day.	Supplement daily.	Daily average gain per gilt in period.
1	None........................	209.8	3.65	none................	0.354
2	Meat meal 1/30..............	210.8	3.21	meat meal 0.127...	0.582
3	Meat meal 4/30..............	210.4	2.75	meat meal 0.432 ..	0.635
4	One-third Grain mix ($O_3B_3M_3OM_2$)....................	217.0	2.73	$O_3B_3M_3OM_2$ 1.07..	0.350
5	Chopped clover and molasses	208.0	3.78	cut clover 1.56 molasses 0.261 ..	0.580
6	Clover (whole)..............	200.0	3.67	clover 0.302.......	0.528
7	Alfalfa (whole)..............	211.6	3.74	alfalfa 1.106.......	0.627

[a] Reduced to shelled corn basis from ear corn figures. Composite samples of the ear corn were taken daily and determinations of the shelling percentage made monthly.

It will be noticed that lot 1 which is fed upon ear corn alone, as well as lot 4 did not make the necessary ½ pound gain per day. The gilts in lot 1 refused to eat sufficient feed during the last 60 days of the period to make the necessary gain; hence we were powerless. Somehow the corn did not seem to be palatable and although the gilts seemed hungry they would not eat, but would whine and squeal for

other feed. The gain of lot 4 is below the standard because they did not relish the grain mixture and hence would not consume enough in the last part of the period to make the required gain.

In order to put before you clearly the data concerning the offspring the following table is presented.

Record of offspring.

Lot number.	Supplement to Corn.	Number in average litter.	Weight of average litter.	Average weight per pig in lot.	Average number pigs saved per sow at weaning time.	Cost per pig at birth.[a]
			pounds.	*pounds.*		*cents.*
1	None	7.6	13.20	1.74	5.2	29.3
2	1/30 M. m.	7 4	14.89	2.01	6.2	7.1
3	4/30 M. m.	8.8	19.62	2.23	7.0	12.9
4	Grain mixture ($O_3B_3M_3OM_2$,	10.6	19.50	1.84	7.4	45.1
5	Cut clover and molasses	7.0	15.32	2.19	4.6	35.4
6	Clover in rack	6.4	14.17	2.21	5.6	13.5
7	Alfalfa in rack	7.6	17.41	2.29	6.4	19 2
	Average of all	7.9	16.30	2.07[b]		

[a] Period covered, 140 days from first breeding day to average day of farrow. Cost, on basis of average farrow of 7.6 two pigs per gilt.

[b] Average weight of all pigs born.

It will be noticed that the lot which received corn alone produced the lightest average litter, as well as the lightest average pig. All of the rations wherein corn was supplemented with a food containing considerable ash and protein show a production of larger average pigs per litter, as well as larger average litters. Where a small quantity of meat meal was fed the increase in the average weight per pig was very marked. When one pound of meat meal was fed with 30 pounds of corn, as compared to corn alone the increase in size of the average pig was from 1.74 pounds to 2.01 pounds. Where proportionately four times as much meat meal was fed or 4 pounds to every 30 pounds of ear corn the increase was even more marked or from 1.74 to 2.23, and this in spite of the fact that the average number of pigs farrowed was considerably larger. It is quite remarkable that in lot 4 where a mixed grain ration of (oats 3 parts, bran 3 parts, middlings 3 parts and oil meal 2 parts) was allowed that even though the average number of pigs was 10.6 per sow, as compared to 7.6 with the corn lot, yet the average weight per pig exceeded the corn alone pigs by $\frac{1}{10}$ of a pound, or practically 6 per cent increase in size. Both the clover and alfalfa had a very marked influence in increasing the size of pigs

born. As compared to corn the ration wherein alfalfa and corn were fed showed an increase in weight of 13.2 as compared to 17.41, or an increase of 31.1 per cent The average weight of pig per litter increases from 1.74 to 2.29 pounds, or a percentage increase of 31.6. It is well to remember that in the alfalfa lot as compared to the corn lot both on the average farrowed exactly the same number of pigs or 7.6 pounds per sow.

Vigor of offspring in percentages of total born. Lots arranged in order of relative vigor, with strongest first.

Lot number.	Supplement to Corn.	Strong.	Medium.	Weak.	Dead.
3	Meat meal 4/30	93.18	4.55	2.27	none
7	Alfalfa	89.47	7.89	none	2.63
2	Meat meal 1/30	91.89	5.41	2.70	none
6	Clover	93.75	none	6.25	none
4	Grain mixture ($O_3B_3M_3OM_2$)	83.02	5.66	5.66	5.66
5	Chopped clover and molasses	85.71	none	11.43	2.86
1	No supplement	68.42	15.79	15.79	none

It is quite remarkable that the ration fed the mother should have such a marked influence upon the vitality of the pigs which are born. The above table is interesting in that it shows the corn pigs of lot 1 to have the least vitality. The "weak" pigs classed in the above table really include a large percentage of runts according to the classification of the hog farmer. It was especially noticeable that the pigs farrowed by the sows which received nothing but corn lacked strength and vigor when born. A number of these seemingly did not have enough ready energy to make life worth while.

Condition of offspring in percentages of total born. Lots arranged in order of relative condition, fattest first.

Lot number.	Supplement to Corn.	Degree of fatness.	
		Prime to medium.	Medium to inferior.
2	Meat meal 1/30	91.9	8.1
3	Meat meal 4/30	87.5	12.5
7	Alfalfa	85.5	14.5
5	Chopped clover and molasses	81.4	18.6
4	Grain mixture ($O_3B_3M_3OM_2$)	74.5	25.5
6	Clover	71.9	28.1
1	No supplement	61.8	38.2

The condition of the pigs was determined by a physical examination shortly after birth. The pigs were all handled, especial atten-

tion being paid to general appearance and the covering over ribs. The pigs in poorest condition were in the corn fed lot. The meat meal fed sows gave birth to the fattest pigs, with alfalfa second.

The cost of pigs at birth is quite a factor in determining whether or not the hog farmer will make a difference in his method of feeding sows during the gestation period. Our results show that larger, stronger, and better conditioned pigs are produced at less cost per pig at birth when correct supplements are fed with corn, than when corn is fed alone to young ungrown gilts. The four lots producing the largest and strongest pigs at birth were likewise the cheapest producers. In these four lots the cost of each new-born live pig ranges from 7 to 19 cents, as compared to the higher cost of 29 cents with corn alone. By feeding supplements then, the farmer is not only assured of larger and stronger pigs, but he should secure them at a less price per head than the weaker pigs fed on corn alone. Intelligent feeding during the gestation period means more money in the pocket of the corn belt hog farmer.

The sows were carried through the suckling period on the same ration as during the pregnancy period with the exception of lots 5 and 6, which were allowed alfalfa instead of clover hay. The clover was replaced by alfalfa because the sows while suckling did not seem to care for the clover, but did relish the alfalfa.

Number of pigs saved at weaning expressed in per cent of total pigs suckled.

Lot number.	Supplement to Corn.	Percentage.
6	Alfalfa	90.3
7	Alfalfa	86.5
2	Meat meal 1/30	86.1
3	Meat meal 4/30	81.4
1	No supplement	72.2
4	Grain mixture ($O_3B_3M_3OM_1$)	71.2
5	Alfalfa	67.7

There is not much comment to make upon this table excepting that the better rations of lots 2, 3 and 7 saved the most pigs. Lot 6 saved the largest percentage, probably because of smaller litters at the start. By referring back to the "Record of offspring" table it will be noticed that there is quite a difference in the number of pigs reared successfully to weaning time. Lots 2, 3, 4 and 7 taking the lead in this respect.

Observations on the color of the offspring.—The color of the pigs at birth is interesting. It was noticed that the pigs from the 3 lots

receiving meat meal had longer, denser, and brighter cherry-red coats than did the pigs from the other lots. The pigs from the sows receiving nothing but corn did not show nearly so heavy and glossy colored coats as the other lots and this was attributed to the following observed factors:

(1) The skin underlying the coat was lighter—approaching a colorless skin—and of a somewhat anemic condition. This would tend to make the coat appear less highly colored than if the skin were pink and rosy as in lot 3.

(2) There was really less coat because of a smaller number of hairs per unit area, and further because the hairs were comparatively short. The apparent differences in coat color were really due to differences in quantity of hair and color of background than to a fundamental difference in color of the hairs themselves.

It is interesting to notice that the mothers in lot 3 had much heavier and better colored coats. We have noticed in our work that meat meal or oil meal is especially adapted to the production of a heavy, sleek and glossy coat. That the youngsters born from these mothers should also show a correspondingly heavy coat is quite remarkable. The theory might be advanced that the pigs from corn fed mothers did not produce a heavier coat because of the lack of elements necessary for its production, and in sacrificing somewhere, along the line of production, it would be logical that the coat should suffer as that is not absolutely essential to the welfare of the pig. A pig can get along vastly better without a coat of hair than without a heart, or bone, or teeth, for instance.

The composition of offspring—A representative pig from a representative litter was taken at birth before suckling from each lot for chemical analysis. Complete determination is now being run, including all of the individual ash constituents. At present only the organic analyses are completed and it is well to mention in passing that these do not show any compositional differences which might be attributable to or correlated to the dam's ration. This we would naturally expect. We find that the largest differences are quantitative and not qualitative. The data impress one that the pigs are built practically upon the same organic composition plan, and that the differences in size of pig are due not to a change in relative composition, but rather to an increase in proportional quantities of all the elements. Our analysis of the new-born pigs show the following range:

	Per cent
Water	76.5 to 81.2
Protein	10.5 to 13.6
Ether extract	1 to 2
Ash	3.6 to 4.6

Dr. A. W. Dox of the chemical section, Iowa Experiment Station, is coöperating with us in the chemical end of this experiment, and the above determinations are from his laboratory. The individual ashes have not yet been determined.

What factors are instrumental in causing a difference in the size of the pigs at birth? In order to study this matter intelligently it is necessary to find out just what a desirable litter is, of what weight, and something concerning the elements required in making it. Let us study the calcium for instance. An ideal litter from gilts will number 9 pigs, averaging in weight at birth 2.2 pounds, or a total of 19.8 pounds. For this consideration we will use 20 pounds, which is practically the same. Twenty-one per cent of this 20 pounds or 4.2 pounds is dry substance, 5.7 per cent of which is calcium. In this litter then, we will expect to find 0.239 pound of calcium. If we are feeding corn alone, how much corn will it take to provide this much calcium? König and Whittier working in separate laboratories analyzed corn to determine the calcium content and they found respectively 0.23 and 0.11 parts of calcium per 1000 parts of dry substance. This averages 0.17 parts. Ordinary corn, well dried, contains about 88 per cent of dry matter. This sort of corn would contain practically 0.15 pound of calcium per 1000 pounds. In order to secure enough calcium in corn to meet the needs of the litter there would be required as many thousand pounds of corn as 0.15 is contained times in 0.236 or 1.573 pounds, or 1573. The young gilt in order to secure enough calcium in the entire period of gestation of 114 days (an average of the 35 gilts in this work shows 114.28 days as the gestation period) would have to consume daily, at least 13.70 pounds. And this on the manifestly illogical assumption that the gilt will digest and assimilate every iota of calcium given to her in the food. But let us continue. Just think of it, 13 pounds of corn per day for these young gilts. In the first place the gilt could not possibly eat this amount of corn and in the second she would not. Corn alone is not palatable enough to be consumed in such large quantities.

Our gilts on corn last winter, toward the end of the pregnancy period, refused feed on a 3-pound daily allowance. Furthermore, if the young gilt could use 13 pounds of corn a day she would not

then be assured of an adequate supply of calcium for her litter, even though it were all digested, because the body voids a certain amount of calcium, regardless of the intake. Even if the 13 pounds of corn did furnish sufficient calcium for the litter, the young gilt which is rapidly growing has no surplus for her own pressing needs, which means that she will ultimately rob her bones to continue her growth. Her bones under this deficiency of calcium will become longer, and more porous. Summing up then, corn does not furnish the calcium necessary for the ideal fetal growth, much less provide for the gilt's growth. No highly desirable surplus is left with which to begin the suckling period. No system of breeding will ever be devised that will provide sufficient stimulus to overcome deficiencies in the building materials actually needed. The only logical thing to do is to feed the needed elements in forms that can be assimilated, and of sufficient quantity to meet the demands of growth. Not until this is done will the breeder be able to get maximum development even *in utero.*

True enough, the mature mother may have sufficient storage of most of the elements in her body to provide for the growth of the fetus even though the supply from without be deficient. With some grown animals this is probably true. The cow for instance, will seemingly develop a normal calf *in utero* even though the feeding stuffs provided are lacking in mineral elements. Remember, however, that the ungrown gilt has a double burden, namely, providing for her own growth as well as for the growth of her fetus. Really there is another burden, that of maintenance, which is common and necessary to all animals. We know that the cow will rob her own body of calcium and other elements, chief among which is phosphorus, to furnish milk for her young. Milk production is a deep-seated maternal function. But this same cow will give more milk, and for a longer period where the needed elements are supplied through the food stuffs. Naturally we expect, and logically, that the sow will put more substance into her fetal young when an abundance of the needed elements is provided in her feed, than if she were compelled to rob her own body stores. The foregoing results which we have pictured to you clearly indicate that the ration has its effect upon the offspring, and further adds evidence to the logic of this argument.

The average calcium content of feeds such as we used in our experiment per 1000 pounds of food stuffs is worth consideration. Corn has 0.15, meat meal 7.6, clover 14.6 and alfalfa 19.3 parts per 1000 pounds. Alfalfa and clover as with most of the leguminous hays are rich in calcium and other basic ash elements. There is over 100

times the amount of calcium in the alfalfa as in corn. One-tenth of a pound of alfalfa or one-fifth pound of meat meal will furnish practically as much calcium as 13 pounds of corn. Ninety per cent of the dry matter of the fetus is produced in the last half of the gestation period. Judging from analogous physiological records on human and sheep fetuses it is safe to estimate that 90 per cent of the dry matter in the fetus of the gilt is deposited *in utero* in the last sixty days of the gestation period. Sixty days is practically three days longer than half of the gestation period with gilts. With this factor as a basis, would it not be logical to provide for the needs of the gilts within this time? Would there be a relation between certain constituents of the food furnished during this latter half of the pregnancy period and the size of the offspring? With this question in mind we have prepared the following table illustrating the possible correlation between the

Amounts of calcium, digestible protein or phosphorus fed during the last half of the gestation period, and the average weight of offspring.

Lot number.	Calcium (total).	Protein (digestible).	Phosphorus (total).	Average weight per pig, new born.
				pounds.
1	0.033	16.43	0.63	1.74
2	0.2118	16.86	0.66	2.01
3	0.7857	24.69	1.07	2.23
4	Not considered because of large incomparable litters.			
5	Not considered because chopped clover was wasted and no record kept of waste.			
6	0.190	18.76	0.78	2.21
7	1.430	26.10	1.106	2.29

calcium, digestible protein, and phosphorus contents of the food stuffs, fed during the last 60 days of the period, and the size of the offspring.

The calcium ranks according to quantity, with smallest quantity first in the various lots as follows: 1, 6, 2, 3, 7. It so happens that the digestible protein ranks in practically the same manner, 1, 2, 6, 3, 7. It is further interesting to note that the average size of the offspring with smallest first, takes the same rank: 1, 2, 6, 3, 7. Plotted curves show the average size of offspring to follow the total calcium content of the ration more closely than the digestible protein with corn alone; calcium is evidently a limiting element. The total weight of litter runs 1, 6, 2, 7, 3 with 6 and 2 very close and 7 and 3 quite so, tending to approximate the placings upon the calcium and protein contents of rations. But it is intensely interesting to note that the size of the offspring is seemingly affected by the content of calcium and protein in the ration the last 60 days of the gestation period.

The phosphorus does not rank in the same order as the calcium and protein, but as follows: 2, 1, 6, 7, 3. It will be noticed from this that the first two lots (2 and 1) and the last two lots (7 and 3) of the phosphorus ranking are reversed as compared to the calcium or protein, or as compared to the average weight of new-born pigs. The actual figures would also show that there was not so much relation between the size of the offspring and the phosphorus content of the ration as the relation between calcium or protein content, and size of offspring. This is probably due to the fact that corn is naturally fairly rich in phosphorus and that there is probably an abundance of this element present to meet the nutritive demands. Surely there is relatively a greater amount of phosphorus furnished in the ration as compared to the demands of the gilt than there is of calcium by all odds. Phosphorus then, is probably not a limiting element as is calcium.

Those venerable physiologists Pröscher and Abderhalden, working in separate laboratories, showed us that there is a marked relationship between protein in the milk and the rapidity of development of the nourishing young. The larger the comparative proportion of protein in the milk the more quickly the animal grows and develops. Pröscher and Pages demonstrated to our delight that the quantity of the mineral bodies in the milk and especially the amount of calcium and phosphorus, stands in close relationship to the rapidity of growth. The amount of these mineral elements in the milk is shown to be greater in animals which grow and develop quickly compared to those which grow more slowly. Bunge, the gifted German physiological chemist, while working at Bâle enriched our live stock knowledge indirectly when he showed that the proportion of the various inorganic substances to each other in milk is almost the same as it is in the whole body of animals, while they are being suckled. These aforementioned investigators show us the possibility of a way in which the fetus may be affected by the constituents of the foodstuffs fed the mother. Of course there is a fundamental difference in the nourishment of the fetus as compared to the nourishment of the born young, but nevertheless there is an actual relationship which suggests great possibilities of the ration and its constituents affecting the growth of the unborn young.

Other investigators have studied the influence of nutrition upon fetal growth, chief among whom are E. N. Wentworth and H. H. Kildee of the Iowa State College. Professor Wentworth showed that with gilts he got larger and stronger new-born pigs when meat meal was fed in conjunction with corn, than when corn was fed alone.

When working with two-year old sows which were practically mature, his results show heavier litters where blood meal was fed with corn, than corn alone. He concludes that "The pigs (new-born) from the narrower ration were the thriftiest, strongest and best able to make the largest gains after weaning . . . . with young sows lack of protein seems to be associated with weakness immediately after birth."

Professor Kildee compared three lots, one of which received corn alone and the two others varying proportions of bone meal. The bone meal he fed contained 60.64 per cent of tri-calcium phosphate. He concludes "The ration of corn alone made the poorest showing for the weight of pigs at birth" . . . . "The pigs from the sows getting the ration richest in mineral matter seemed somewhat more vigorous at birth, and had quite an advantage in weight of pigs at birth. . . . . When corn meal was the sole feed the addition of mineral matter resulted in somewhat stronger bone, thriftier and heavier pigs at birth." Professor Kildee worked with old sows entirely. The results would have been quite interesting indeed had he supplied protein as well as bone meal to another lot to have been compared to the above mentioned three. In light of our present knowledge this would have produced the much larger and stronger pigs at birth.

That the development of the organism *in utero* may be hindered by lack of proper nutrition, offers a broader field of thought for breeders. Ruminants are not so likely to suffer in this regard. But the sow is so situated in a corn environment that with her the securing of the necessary sustenance for her unborn young is a matter of common concern. Unskilled feeding during gestation days makes maternal sacrifice of bodily stores imperative. That swine may store for the future from a bountiful supply of summer grasses is fortunate indeed. The greater the bodily storage of those necessary elements that go to furnish the building material for the generation unborn the less severe the maternal sacrifice, and the more luckily fortunate the resulting offspring. Still more advantaged though, are those new-born young whose mothers have an optimum of organic and inorganic nutrients during the period of pregnancy.

Note:—July 15, 1912. Forty pregnant sows and 20 gilts corroborate in a large degree the foregoing earlier results.

FURTHER REPORT ON INHERITANCE OF HORN AND WOOL COVERING IN SHEEP

T. R. Arkell

Durham, N. H.

This paper represents a review of the experimental work that has been thus far completed in breeding horned and hornless sheep together. Owing to the fact that it is not a good plan to breed ewe lambs, the work has progressed slowly. A large number of the F_1 generation has been obtained, but comparatively few of the F_2. The 1912 crop of lambs, it is hoped, will bear from 30 to 40 F_2 individuals. We shall then be placed in a position to describe more definitely the manner of inheritance of horns in sheep.

In studying horns we first found it necessary to appoint some common factor whereby we could describe and compare accurately all sizes and degrees of horns. The ratio of circumference to length was taken for this purpose. This is attained in the following manner: Two measurements of length are made from the poll to the tip of the horn, one on the inside and the other on the outside of the horn. An average of these is taken and the result represents the length of the horn. The circumference is taken as close to the poll as possible.

The first problem that presented itself was the effect or relation of age to the ratio; or, in other words whether the ratio was constant at all ages. Without definite knowledge in this regard many errors might easily enter that would greatly depreciate the scientific value of the data. To this end measurements of Dorset rams and ewes were made every month from birth until a constant ratio was attained. It was discovered that not until eighteen months of age did the horns reach a stage of perfect maturity beyond which appreciable fluctuations in size no longer occurred. The circumference at first expands to a greater extent than does the length, consequently giving a less ratio. So far as we have been able to judge from data at hand there seems to be no definite rate of increase in growth, nor is it in any way comparable to the growth of the body. When work of gathering this data was commenced, we had in mind only the desire to be able to recognize the period when variations in horn growth ceased. Since then a new avenue of research has been opened up, namely, variations in the rate of growth and the possibility of an inheritable tendency in this respect.

At three months of age the ratio (length divided by circumference) of horn measurements of the rams averaged in round figures 2.00,

of the ewes, 1.60; at six months the rams 2.60, the ewes 2.00; at one year the rams 3.25, the ewes 2.50; and at eighteen months the rams 3.40 and the ewes 2.70. The average ratio of a matured horn, according to our measurements of twenty-four Dorset Horn rams and ewes, was for the ram 3.44 and for the ewe 2.72. This, I admit, does not represent altogether a fair average, since only 12 individuals of each sex were included. In order to establish a more exact average, measurements of several hundred sheep should be made. However, in all instances the ratios ran fairly evenly, the difference between the highest and the lowest in the ewes, which was the greatest, being 0.33 points. The difference between the ratios of the horns of the rams and the ewes may be represented by a coefficient which expresses the ratio of the one in terms of the other. In this instance with the data we have at our disposal the coefficient would be 1.26. However, as I have already pointed out, this factor, owing to the comparatively small number of measurements of typical long horns we have been able to make, should not be adjudged as absolute. We have used it only in making rough comparisons.

Many Rambouillet ewes possess quite large horn excrescences that, however, do not break the skin. These excrescences are not measurable although they sometimes protrude as much as an inch and a half beyond the skull. This peculiar feature we have called, in brief, "a knob." Any horn having a ratio less than 1.00, we have designated a "scur" and beyond that "short," "medium" or "long" horn as the ratio justifies.

Where reciprocal crosses were made of a long horned sheep with a hornless sheep, the females were invariably polled and the males always possessed some indications of horn growth, varying all the way from minute scurs to a medium-sized horn. The longest horn from such a cross had a ratio of 2.91 and the shortest consisted of a scur with a ratio of 0.32. Reciprocal crossesof horned father and polled mother or vice versa gave horns in the male offspring very similar in character or, at least, no appreciable difference could be discerned. It is true that the average ratio of the horns of male individuals from each cross was 0.26 points higher where the mother was horned, yet this is due to the fact that one individual, compared with the average of this cross, had abnormally long horns. This, however, is a marked exception. By removing it, the average in both instances is virtually the same.

A peculiar feature of the heterozygous horn in this and other crosses comprehends a lack of similarity in size betwixt the right and left

horns of many individuals. This difference expressed in terms of the ratio is at times as high as 0.45 and the average of all cases, being 76 per cent of the total horned F_1 generation, 0.18. The right and left long horns of the Dorset are almost invariably uniform although in 6 per cent of cases examined a very slight difference did exist. Nor does one horn possess an advantage in size over the other, for in 52 per cent of total cases the right horn was the longer; in 48 per cent, the left. However, in the F_2 generation, in so far as our limited data show, this irregularity disappears to a large extent, which doubtless means a return to the pure horned condition, although such horns are not quite so long as the horns of the horned grandparents.

The knob of the Rambouillet ewe is clearly a sort of incipient horn to which, however, sufficient growth stimulus has not been supplied to permit a complete somatic development. So far as our knowledge extends the knob condition exists only in Merino sheep and will be present in females, without producing a scur or horn, through successive generations. Our records show that when crosses with other breeds are made, it disappears, the female offspring possessing either an entire absence or a long horn according to the nature of the mating. When a ewe bearing the knob character is crossed with a long horned ram other than a Merino, the offspring, both rams and ewes, possess long horns. We have had no exception as yet to this rule, our knowledge, however, comprehending but twelve examples. The length of the horns of the F_1 offspring, although the ratio of length to circumference is less than that for the long horns of the Dorsets, clearly entitles their inclusion in the long horn class. The offspring from matings between a hornless ram and a ewe bearing knobs are in every respect similar to those of a hornless and a long horned sheep: the females show an entire absence of horn growth and the males bear the usual heterozygous intermediate horns. The horn growth (knob) of Rambouillet ewes will at times break through the skin but seldom to form an appreciable horn, usually a mere scab.

Scurs, except where the knobs of Rambouillet females have disrupted the skin, are heterozygous horns. We have tested 4 F_1 rams, bearing heterozygous horns, two scurs, one a small and the other a medium horn, by breeding each upon 3 pure polled and 3 pure horned ewes. The scurs seemed as potent in producing long horns in the offspring as the small or medium horns. Therefore, the results can be combined without rendering their interpretation misleading. Fourteen offspring, 6 rams and 8 ewes, were obtained from the pure polled ewes. Four rams possess heterozygous horns similar to the fathers;

the other 2 are polled. The ewes are all hornless. Only 11 lambs 6 males and 5 females, were born of the pure horned ewes. Two rams appear to have long horns, although the horns are not fully matured yet; 2 have scurs and the others, short horns. Two females have long horns; the other 2 are polled. The data, I admit, is so scanty, it does not permit of any sweeping inferences, nor can we estimate whether Mendelian proportions are followed. However, in the former case we would expect a complete absence of a horn factor in the germ plasm of the hornless rams, but the character of the ewes can be determined only by subsequent test breeding inasmuch as some may be heterozygous bearing a single horn factor which upon a favorable combination may in a later generation develop a horn growth. In the latter case the horned female apparently possesses a pure long horn and the 4 that are hornless are heterozygous in regard to horns, for their mothers possessed homozygous horns and the father was plainly a heterozygote in that respect, being the product of an assuredly pure hornless male and a pure horned female. Therefore, the hornless F_2 females must hold in their germ plasm one horn factor.

Matings between hornless sheep invariably produce hornless females and males that are either hornless or possess intermediate horns. The hornless females may be pure or heterozygous which selective breeding alone will show, unless their lineage for several generations is known. The hornless males cannot reproduce a horn. The experience of practical breeders provides proof to this end and in our own breeding operations hornless males bred upon recognizedly pure hornless ewes have never produced in the male offspring the slightest semblance of a horn. The horned males of this cross are clearly heterozygous.

It has been my purpose in this paper to state as concisely and interestingly as possible our results at New Hampshire Experiment Station in experimental breeding of sheep in so far as the horn character is concerned. Extensive breeding of sheep for this purpose is a slow operation, since ewes must remain until they are yearlings before they can be bred satisfactorily. From what proof is already before us it is patently demonstrated that the horn condition is dominant. In heterozygous rams an intermediate horn, varying in size all the way from a scur to a medium horn, appears. However, in heterozygous ewes no horn whatever develops. The following theory explains thus far satisfactorily this phenomenon. It is evident that the presence of but one horn factor in the germ plasm of the female does not provide sufficient stimulus for the somatic development of even the slightest

vestige of horn, since the foregoing data shows that the knobs and scurs of Rambouillet ewes transmit upon crossing, long horn qualities in a similar fashion to a pure long horned ewe. This, therefore, points in the latter condition, to the existence in the germ plasm of both horn determiners. It is probable that in the female germ plasm there exists some factor unfavorable to somatic horn growth, or in other words an inhibitor (designated in the table by the symbol I, its absence by i), which is associated with femaleness as a homozygous dominant, but is simplex (heterozygous) in the male, the inhibitor being located on the sex chromosome. Therefore, both horn determiners must be present in the female germ plasm before horn growth can be produced, for the double inhibitor is capable of preventing the development of the single horn (Hh) determiner, but not the double determiner (HH). In the zygote where only a single inhibitor is present, the simplex horn will develop. This theory consequently must presuppose, as well, the female to be duplex in regard to sex (XX); and the male simplex (Xx). This conditions has been found by Guyer (1910) to hold true for man.[a]

The table on page 566 explains the nature of the matings that have been made. A part of the data derived from breeding experiments with Scottish four-horned sheep has been furnished by Dr. C. B. Davenport of the Station for Experimental Evolution, Cold Spring Harbor, Long Island, with whom this Station coöperates. The actual number of offspring obtained from each mating is given and above them in parentheses is shown in the complex cases the expected proportions of frequency.

Wool covering.—Wool covering of head and legs constitutes an important factor of the modern breeds of sheep. The extent of covering frequently enable the novice to distinguish the different breeds. It is true and is to be regretted that in many instances fashion born of showyard practices has placed an emphasis upon certain styles of wool covering far exceeding the intrinsic value. It has, in fact, become a fad with many breeders who pay more attention, in selecting their breeding animals, to perfection of wool covering and other equally fancy features than to characters of commercial utility.

It is known that some breeds as the Shropshire, have an extensive wool covering on the head, surrounding the eyes and closely approaching the lips. The wool also covers the legs to the pasterns The opposite of this condition is seen in the Leicester or Suffolk Down

[a] For a more complete report on the inheritance of horns in sheep, see Bul. 160 of the New Hampshire Experiment Station.

Matings of horned and hornless sheep.

	Determiners in germ plasm of		Number of horned and hornless offspring.			
	Male.	Female.	Males.		Females.	
			horned.	*horn-less.*	*horned.*	*horn-less.*
soma	*XxhhIi* (*hornless*)	*XXhhII* (*hornless*)				
gametes	*Xhi*	*XhI*				
	xhi					
zygotes	*XxhhIi* (*hornless*)	*XXhhII* (*hornless*)	0	4	(0)	12
soma	*XxhhIi* (*hornless*)	*XXHhII* (*hornless, simplex*)				
gametes	*XhI*	*XHI*				
	xhi	*XhI*				
zygotes	*XxHhIi*	*XXHhII* (*hornless*)	(2)	(2)	(0)	(2)
	XxhhIi (*hornless*)	*XXhhII* (*hornless*)	2	2	0	2
soma	*XxhhIi* (*hornless*)	*XXHHII* (*horned*)				
gametes	*XhI*	*XHI*				
	xhi					
zygotes	*XxHhIi* (*horned*)	*XXHhII* (*hornless*)	15	0	0	24
soma	*XxHhIi* (*horned, simplex*)	*XXhhII* (*hornless*)				
gametes	*XHI*	*XhI*				
	XhI					
	xHi					
	xhi					
zygotes	*XxHhIi* (*horned*)	*XXHhII* (*hornless*)	(0.5)	(0.5)	(0)	(8)
	XxhhIi (*hornless*)	*XXhhII* (*hornless*)	0	1	0	8
soma	*XxHhIi* (*horned, simplex*)	*XXHhII* (*hornless, simplex*)				
gametes	*XHI*	*XHI*				
	XhI	*XhI*				
	xHi					
	xhi					
zygotes	*XxHHIi* } (*horned*)	*XXHHII* (*horned*)				
	XxHhIi } (*horned*)	*XXHhII* } (*hornless*)				
	XxHhIi } (*horned*)	*XXHhII* } (*hornless*)	(7.5)	(2.5)	(2)	(6)
	XxhhIi (*hornless*)	*XXhhII* } (*hornless*)	6	4	1	7
soma	*XxHhIi* (*horned, simplex*)	*XXHHII* (*horned*)				
gametes	*XHI*	*XHI*				
	XhI					
	xHi					
	xhi					
zygotes	*XxHHIi* (*horned*)	*XXHHII* (*horned*)	(10)	(0)	(4)	(4)
	XxHhIi (*horned*)	*XXHhII* (*hornless*)	10	0	4	4
soma	*XxHHIi* (*horned*)	*XXhhII* (*hornless*)				
gametes	*XHI*	*XhI*				
	xHi					
zygotes	*XxHhIi* (*horned*)	*XXHhII* (*hornless*)	5	0	0	8
soma	*XxHHIi* (*horned*)	*XXHHII* (*horned*)				
gametes	*XHI*	*XHI*				
	xHi					
zygotes	*XxHHIi* (*horned*)	*XXHHII* (*horned*)	6	0	14	0

where there is no wool on the head in front of the ears nor any on the legs below the knee and the hock. The other breeds represent various gradatory stages between these two distinct types.

Crosses were made of these different types. The greatest area of wool on head, where it extended to the lips, was given a grade of ten; the least, where the head was bare in front of the ears, zero. A similar system was employed in respect to wooling of legs, namely, heavy wooling to pastern received a grade of 10 and bareness on the legs below knee and hock, zero. The wooling on the legs corresponds so closely to that on the head that for convenience I shall discuss only the latter.

The area of wool on the head was obtained by first measuring the face along the nose ridge from the horn pits to the ends of the nostril, underneath from the point of the jaw to the lips, transversely across the head from the point of the jaw to the horn pits and longitudinally along the head from the end of the nostril over the eye to a point which if extended would meet the horn ridge. The distance which the wool descends upon the face is also measured along the same planes. If, per example, the length of the face along the nose ridge is 100 mm. and the wool descends 75 mm. then the wool must cover three-quarters or 75 per cent of the face along that plane. This position is accordingly marked on a drawing representing a standard head and when the other measurements and ratios are obtained a complete drawing can be made showing clearly and precisely how far the wool descends.[b] Diagrams of wool covering of the father, mother and offspring are made upon the same standard outline of a head, each being represented for the sake of distinction by solid, dash and dotted lines respectively. This method enables one at a glance to recognize the nature of the cross.

In 14 cases where a high grade was crossed with an extremely low one the offspring possessed a grade virtually midway between those of the two parents. In 7 other cases considerable variation existed, but in no instance did the grade of any offspring exceed the grade of the parent possessing the heaviest covering or, for that matter, come within 25 per cent of it. Even in less distinct crosses the wooling of the offspring was usually intermediate. Of 99 F_1 offspring only 12 were not intermediate, and of the exceptions 3 were behind the least advanced parent and 9 equal to the most advanced. Therefore, so far as the foregoing evidence shows, wool covering tends, in the succeeding generation, to form a blend. This character has been studied in

[b]A representative drawing is contained in article by author in Proceedings A. B. A., vol. vii, p. 259.

12 F_2 individuals. Eleven show a further reblending or are intermediate to the F_1 parents who in themselves were intermediate to their parents. One, however, has apparently assumed the type of the father's mother who possessed the highest grade of any of his ancestors. The outline is very similar although the grade of the grandson is a half point less. This evidently points to Mendelian segregation, but since it is the only one of relatively few examples, no inferences can yet be drawn. It is interesting, however, to note the prevalence of blending and reblending which apparently does occur throughout consecutive generations. It should also be stated in closing that wool covering appears to be inherited entirely independent of sex difference, for reciprocal crosses gave in all instances similar results.

DUAL PURPOSE AND TOTAL FAT PRODUCTION

E. N. WENTWORTH

Ames, Iowa

For a full century the possibility of a dual purpose cow, popularly and for advertising purposes called a "farmer's cow," has been brought to the attention of the practical farmers, the agricultural press and the agricultural college. All kinds of inducements from a calf nurse to a butter producer have been offered as bait to those momentarily discouraged with special purpose herds. The high price of land and higher cost of production has been cast as a shadow over the beef raiser particularly, and the older writers have dipped into a past when butcher and consumer were not so exacting in their demands, and resurrected, true to their beef tastes, the Milking Shorthorn. Theoretically the two-purpose animal has seemed a nearly accomplished type to the sanguine breeder, and various breeds foreign to America, have had spectacular advents and advertising. In almost all cases mediocrity or even oblivion has greeted both breeder and breed alike. At the present day a few earnest workers still wrestle with the problem, but public favor does not uniformly claim their production. Something must lie behind the problem other than the unrestricted range and live stock outlet of the last century. The writer has looked into the subject from the standpoint of total fat production, and apparently has found one place in which efficiency may be halted.

The horse breeder and buyer is familiar with a so-called farm or general purpose horse, suitable for light draft, road work and rough field traveling, to more than a limited extent. Breeders of other classes of live stock have argued from the horseman's success that dual functions may be developed in their own animals. There lies in horses one important difference that is not found in any other class of animals. The horse's function lies in the propulsion of greater or lesser loads at lesser or greater speeds. Certain typical conformations are adapted to each kind of work, but for gradations of work between, there are proportional gradations in type and these are gradations found in nature between the "forest" and "plains" types of horses. The writer does not mean to say that these intermediate types equal the true roadster or drafter. Ample evidence that they do not is furnished by the fact that all pure breeds strive to attain only the specialized type. Only one function is involved however in the animal's work and slight changes in bone leverage really determine the class to which it belongs.

In cattle, however, two entirely different functions are involved. The production of body fat, or even its possibility, has always seemed inimical to butter fat formation. The earliest text-books on animal breeding quote this as an orthodox example of negative correlation, and the belief has been deep seated with practical breeders. At the outset then, the condition is much different than the horse and offers an entirely different aspect for the student. In one year the profitable dairy cow of mature age should bring forth 275 to 300 pounds of butter fat. This is produced in connection with 550 to 650 pounds of proteids, casein and other substances classed by the milk analyst as "solids not fat." The average daily production then would be from $\frac{2}{3}$ pound to 1 pound of fat and $1\frac{1}{3}$ pound to 2 pounds of solids not fat. Compared on this daily basis the beef steer shows most favorably, two year olds making from 2 pounds to 3 pounds of gain during the early part of their feeding period and distributing the fat and flesh growth in about the same proportions. As to cost of production of each, from 6 to 8 pounds of dry matter are required for 1 pound of butter fat and for 1 pound of growth per steer in the early part of his feeding.

In this connection there occurs a point in the economy of the two types that receives little consideration. The beef feeder claims that he must get from one animal almost as much gain as the dairy cow gives in butter, in order to keep them equal as producers. He forgets, however, that there is a hint of impossibility in it, for while the

dairy cow's milk is removed daily, the beef animal's fat cells become more and more fully packed. As a result the dairy cow is in a position to start over afresh after each milking, while the beef animal with its store houses gradually fuller, must either cut down its food supply or waste a good share of the nutrition in the endeavor to put the ripeness into each cell. It has been experimentally demonstrated that the last portion of fat put in the cell must be deposited under wasteful conditions of feeding or not at all. We can thus amply demonstrate that a year's beef production, or the production at the close of the feeding period cannot in justice to the steer be reckoned in comparison with the dairy cow. His physical limits bind him for long periods, while for short periods, he stands on an equal basis with the dairy cow. If placed on the long period basis, however, the first half of his work must be simply growth without full fattening development When such comparison is made we find some 600 pounds of development whose average pound value nearly equals the pound value of total solid produced by the dairy cow.

The examination of high records offers the same conclusion. Colantha 4th's Johanna, champion dairy cow of the world produced 998.26 pounds of butter fat. Shamrock II, the grand champion of the 1910 International, gained 784 pounds in eight months and was under twelve months of age when killed. When age and time are considered the steer's record is just as outstanding. The point that the writer has been trying to substantiate with these figures, is that on a performance basis, each in its peculiar conditions, the beef steer and dairy cow are almost equal as producers, or at least, are relatively fixed in their relation.

What about the dual purpose cow in this connection? Nature almost absolutely shows that in the same animal the stimulation of one function means an atrophy of the other. Yet we are in the peculiar position of saying that our dual purpose animal must have these, and a reversible function as well, according to the needs which she must meet. Nature permits a limited degree of adaptation, but certainly not a specialization of what are apparently partially exclusive functions. The other alternative offered is that the dual purpose cow must possess a higher capacity for total production, perhaps twice that of the dairy or beef animal, and can thus profitably compete because of her greater total possibilities. The comparison may be made to the child's "see-saw" or "Teeter-totter." The fulcrum represents the inherited energy capacity of the animal and one end of the board, dairy, the other, beef production. A lifting on one end does not

raise both but the average energy capacity of the race is concentrated only on the raised end. If another see-saw or class of animals is to reach the same height on one side, its energy capacity or fulcrum must be raised so that both ends of the board, or the production, may rise together. This seems to the writer to be the case in the dual purpose cow, and while some breeders may and do have animals whose steers win favorable places in the International carcass contest, and whose cows produce with the average of good dairy cows (reference is made to the herd of Red Polled cattle of A. P. Arp, Eldredge, Iowa), yet the fulcrum of his herd, the total energy capacity, must lie far above that of his special purpose competitors. This then would explain why the economies of the past have not permitted as great a development and would also account for the relative infrequency of such animals when their average performances (from a special purpose standpoint) must represent so much greater an inherent capacity.

Turning now to sheep, we find the same condition obtaining. From lamb to yearling form, the well fed sheep will develop about 100 pounds of which 20 to 24 pounds is fat. In wool sheep the fat is represented by a heavy oil secretion, which furnishes as strong a drain on the food supply as does fattening. From 18 to 25 pounds is produced by the best wool types yearly. Six to seven pounds are found in a 12-pound fleece on shearing, and the remainder is removed by evaporation, rain and contact with objects, such as pens and buildings, during the year. The government is conducting an experiment for a muttony wool sheep near Laramie, Wyoming, and the Iowa experiment station has, by crossing, produced a flock of similar nature but of a more economic character. However, the same comparison obtains even here, and strong variations which come near to the special purpose animal, are accompanied either by a decrease in the other function or else such an outstanding nature individually that they are proportionally comparative only to the best of the special purpose animals.

It must not be assumed that the writer is zealously opposed to a dual purpose animal. It is only in search of a physiological explanation for the slow growth in popularity that this idea was conceived, and it may not have the importance the writer believes. It seems unquestionable, however, that some influence must result and the suggestion is offered only for what it is worth.

SEGREGATION IN CATTLE

E. N. Wentworth
Ames, Iowa

About ten years ago there was instituted at the Iowa State College an experiment on the crossing of black polled Galloway cows with a white Shorthorn bull. The economic value of the blue roan polled offspring was established and from the residue of the experiment—1 blue-gray bull, 5 blue-gray heifers, 4 Shorthorn cows and 3 Galloway cows—the present investigation was started. Reproduction is relatively slow, cost of maintenance high and uniform development

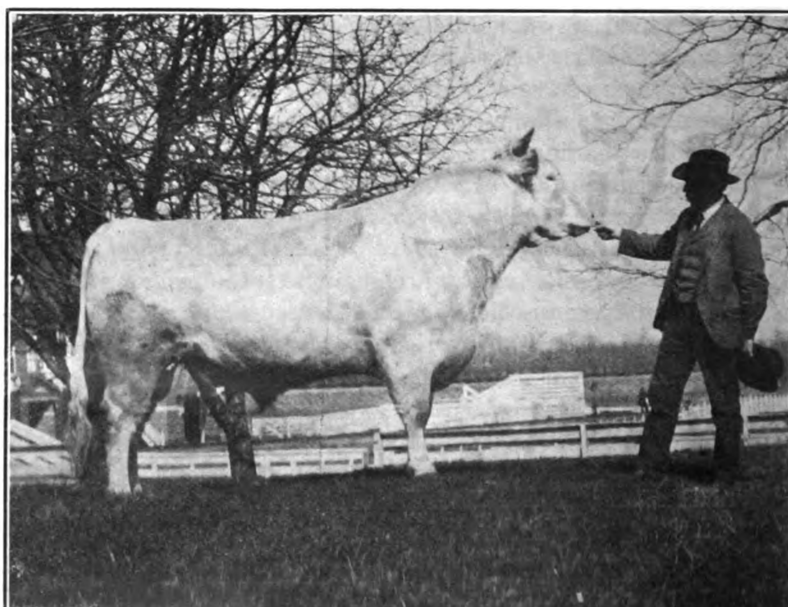

FIG. 1. SHORTHORN BULL, DOCTOR WHITE.

impossible, so the characters studied have been limited to a few that are probably uninfluenced by ordinary care. The work is being prosecuted by Prof. W. J. Kennedy and Prof. J. M. Evvard of the Animal Husbandry Experiment Station, with whom the writer is in coöperation.

A white, horned bull, Dr. White (fig. 1) registered in the *Shorthorn Herd Book,* was mated for three successive seasons with pure bred and grade black polled Galloway cows such as shown in fig. 2. Only

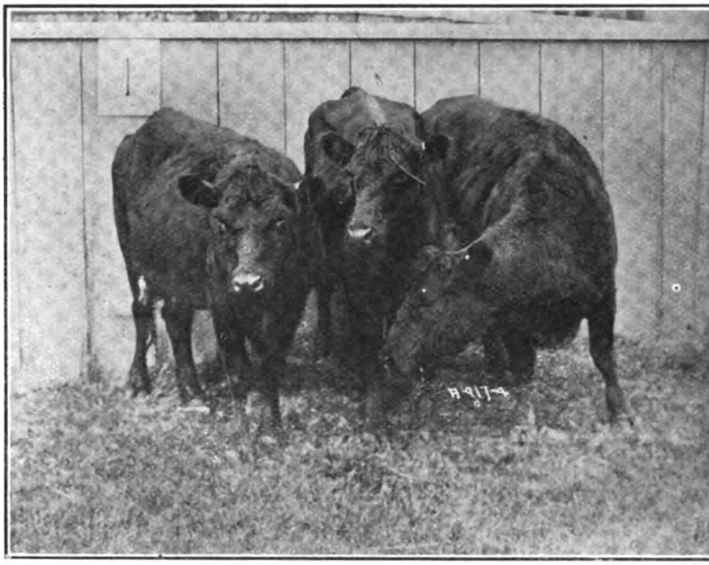

FIG. 2. PURE-BRED GALLOWAY COWS.

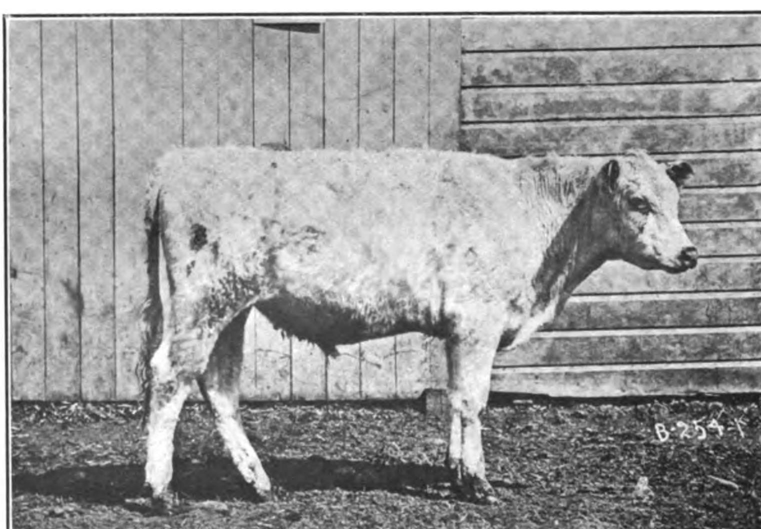

FIG. 3. BLUE-GRAY BULL, F.

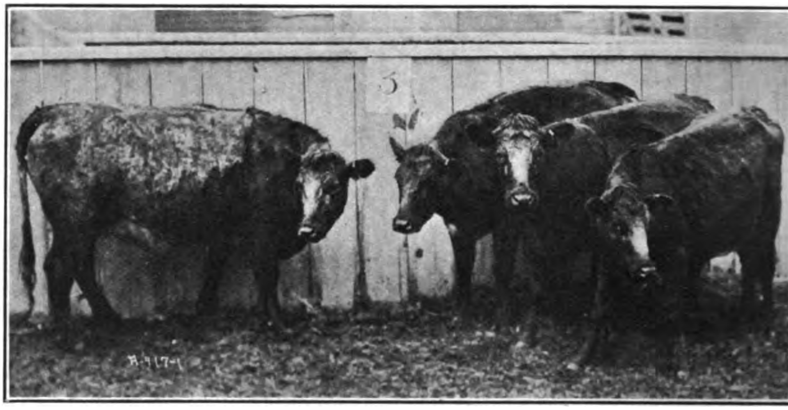

FIG. 4. BLUE-GRAY COWS, F_1.

polled offspring resulted. They were blue-gray in color, i.e., white hairs were mingled with the black similar to the red roan pattern in Shorthorns, and they showed no tendency toward a blending or segregation in the length or furriness of coat. From the third crop of calves was reserved the blue-gray bull (fig. 3) and 5 blue-gray heifers, 4 of which are shown in fig. 4.

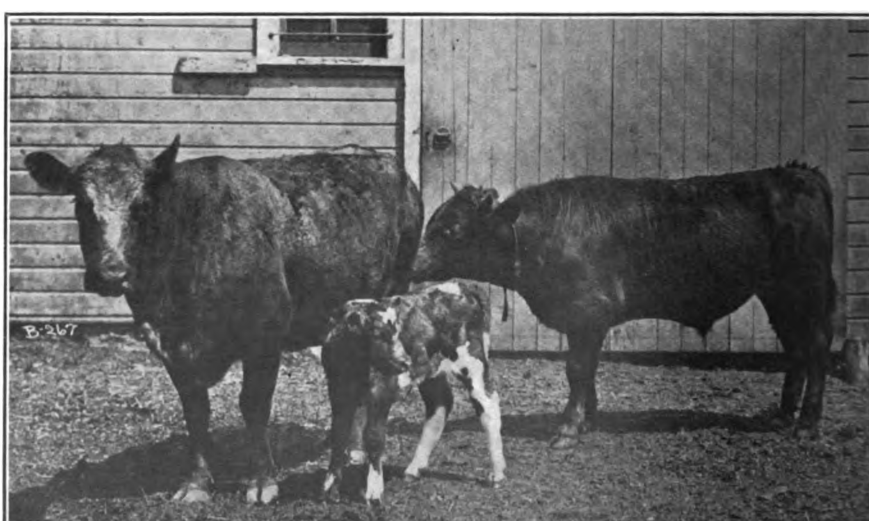

FIG. 5. BLUE-GRAY COW F_1.

Showing two successive calves by the bull, shown in fig. 3. The yearling is black and horned while the calf is red and white spotted and polled.

The mating of these two types has brought forth some interesting results. Fig. 5 shows the produce of cow No. 56 for two successive years. The older calf is black and horned, the younger is red and white spotted, and polled. Since then she has produced a polled black bull calf with blue-gray head and white navel, while previously she gave birth to 2 blue-gray and white heifers, one polled, the other horned. All of these have been to the service of the blue-gray bull and previous to the last calf, she had given rise to simple Mendelian proportions exactly, the red and white being as typical a Shorthorn color as the white found in the grandsire. The writer must not be misunderstood on this point, however, as it is highly doubtful if the color is thus simply transmitted. In fact, the evidence to date shows

FIG. 6. F_2 HEIFERS.
One dark blue-gray and polled; one blue-gray and white polled; one horned, blue-gray and white.

that it is extremely complicated, but suggests ideas similar to those advanced by Mr. H. H. Laughlin in the *American Naturalist* of December, 1911. In fig. 6, 3 blue-grays of varying intensities are shown, 2 of them polled, 1 horned. These are part of the heifers which are mothers of the F_3 generation. The white steer shown in fig. 7 is typical of a large number of animals which have come in the experiment. Up to date no white color has completely segregated as in Dr. White of the parental generation. All have shown the dark coloring at muzzle, eyes and ears while some have shown dark switches, dark tufts of hair at sheath and dark ankles.

The question of a homozygous polled character has been hard to determine because of economic considerations. The bull of fig. 8

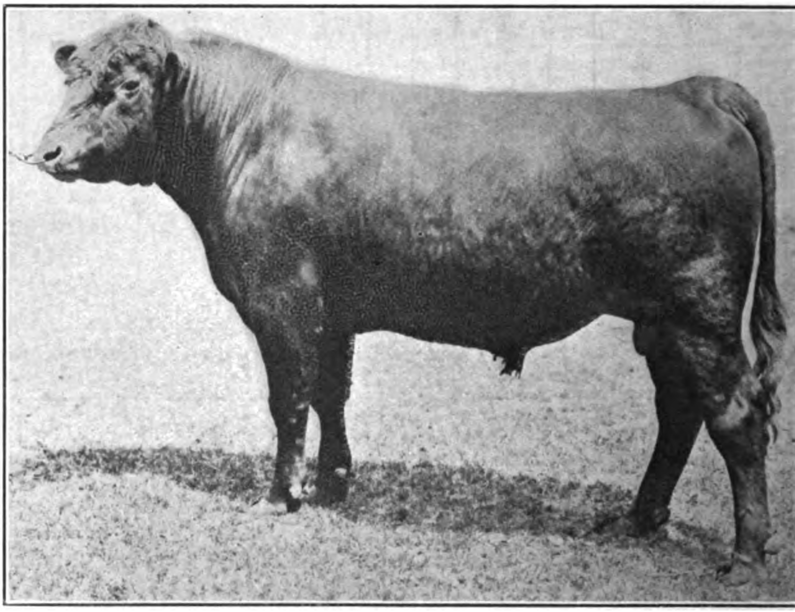

FIG. 7. F_2 STEER,
White polled, and possessing the bluish black extremities common to the "Park Cattle" of Engand.

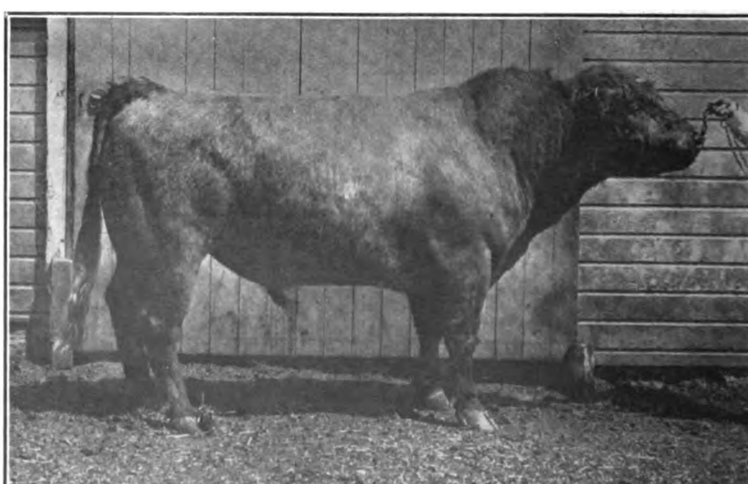

FIG. 8. POLLED RED BULL, F_1.
Undoubtedly pure polled as only polled calves have resulted to his service on horned cows.

has sired only polled calves as in fig. 10. The color of this bull is of interest, for although solid red, he displays not typical Shorthorn pigmentation, but rather a "brickier" red of the Galloway type. Prof.

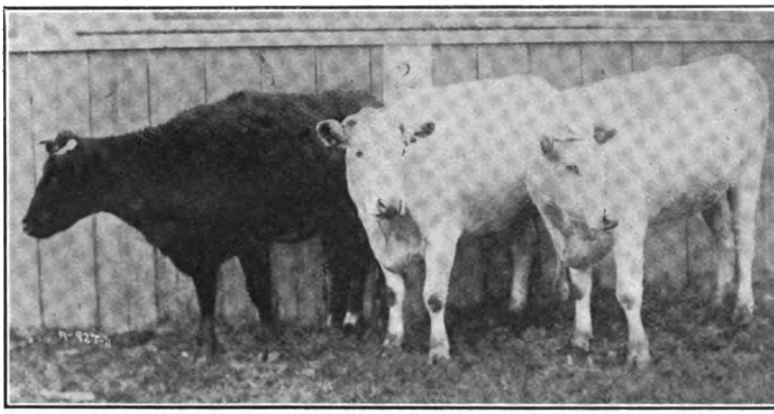

FIG. 9. SHORTHORN COWS.
One red and two white. Mated to the bulls of fig. 3 and fig. 8.

Robert Wallace of the University of Edinburgh while visiting this country in 1909, particularly made note of this fact. This offers a suggestion as to the segregation of the Galloway colors but it does

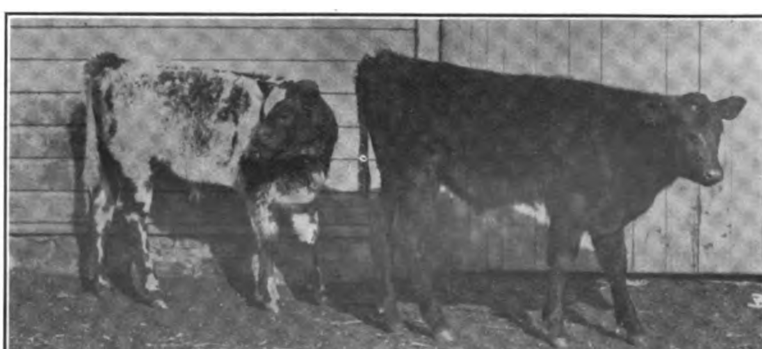

FIG. 10. CALVES PRODUCED THROUGH THE MATING OF THE SHORTHORN COWS OF FIG. 9 TO THE POLLED RED BULL OF FIG. 8.
One calf is red, the other red roan. Both are polled.

not offer a readily measurable character. In fact as the bull grows older he comes much nearer the red characteristic of the Shorthorn.

The breeding of the blue-gray bull, F_1 back to the Shorthorn cows of fig. 9 furnishes much interesting data. Mated to white cows,

2 white calves and 1 blue-gray resulted; while mated to red cows 2 red calves and 1 blue-gray came. Of these only the first mentioned blue-gray was polled.

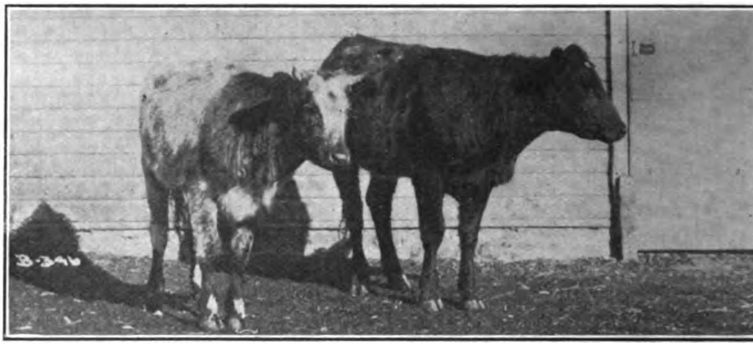

FIG. 11. CALVES PRODUCED BY MATING THE BLUE-GRAY BULL OF FIG. 3 TO THE SHORTHORN COWS OF FIG. 9.
One dark blue-gray and polled; the other light blue-gray and horned.

The mating back of the blue-gray bull to the pure bred Galloway cows of fig. 2 furnishes the real anomaly of the experiment and whether one refers the result to a lack of purity in the polled character of two of the females, or whether to a reversal or imperfection of domi-

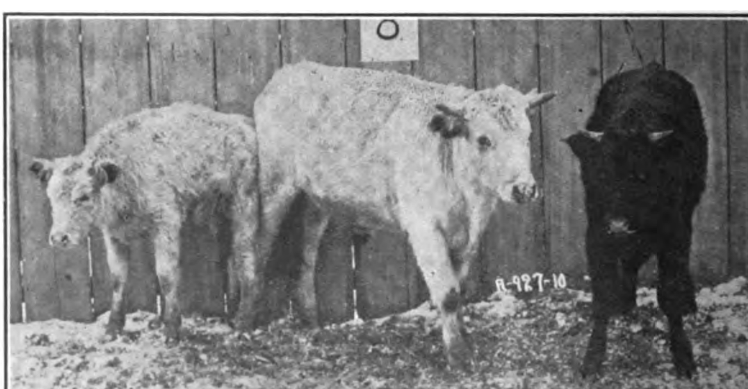

FIG. 12. RED HORNED AND WHITE HORNED BULLS AND WHITE HORNED HEIFER.
Produced by mating blue-gray bull of fig. 3 to shorthorn cows of fig. 8.

nance in the bull, the result is equally unorthodox. Fig. 13 shows 2 polled black calves typical of most of the offspring from the cross, but fig. 14 shows a steer and heifer both horned. Why from the mat-

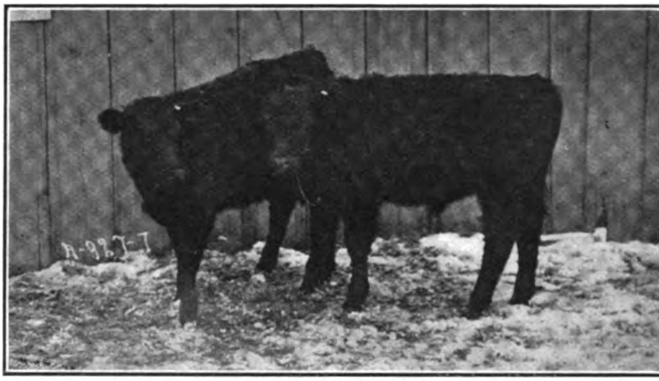

FIG. 13. POLLED BLACK CALVES.
Out of Galloway cows (fig. 2) by the blue-gray bull (fig. 3).

ing of a hybrid polled bull to pure polled cows, horned animals should result, is difficult to explain. The heifer (right hand) shows fairly typical Shorthorn horns, but the steer shows a heavy spike horn of a totally unrelated variety. The Shorthorn bull, Dr. White, did not have the "breediest" horn one could ask for, but neither did he possess a suggestion of the horn here shown. The mother of the polled heifer shown on the left in fig. 14, produced only polled calves; the

FIG. 14. ANIMALS PRODUCED BY MATING THE BLUE-GRAY BULL OF FIG. 3 TO THE GALLOWAY COWS OF FIG. 2.
Horned black bull in center, horned blue-gray heifer to left and polled black heifer to right.

mother of the horned steer produced 6 polled calves in addition to the horned one; but the mother of the horned heifer produced a horned steer as well as 4 polled calves. The behavior of this horned heifer when bred is interesting. Mated to a horned Shorthorn bull she gave a horned calf, but mated back to her own sire (the bull of fig. 3) she gave a polled calf. If the cause of the horn was a modification in dominance then the polled character was dominant again when mated to the daughter. If the Galloway cows were heterozygous, then the 6 polled calves from the two cows, produced to the service of a homozygous horned bull, illustrated how chance may obscure the truth.

In addition to the matings already given, the following lines of breeding have been partially investigated. Too few calves have come, to base any conclusions on, but the types are of interest. The horned blue-gray heifers of F_2 have been mated to the F_1 blue-gray bull; the polled blue-gray heifers of F_2 have been mated to a white horned bull (Shorthorn); the daughters of the Galloway cows by the blue-gray bull have been mated to him, to a white Shorthorn and a roan Shorthorn; and the F_2 polled blue gray heifers have been mated to the last named bull. So far all F_2 horned blue-grays to the blue-gray bull have given 50 per cent horned calves and all polled F_2 blue-grays have given polled calves on mating to horned bulls.

Long as the experiment has been in progress, it must be considered as only in a preliminary stage. Many factors occur to discourage one, not the least of which is the high mortality of calves at parturition due to the extreme size of foetus. Many of the heifers have produced calves that exceeded 10 per cent of the heifer's live weight, and the resultant stunting of the mother has comparatively magnified the vigor of the F_3 individuals in relation to the F_2. Whether such additional vigor is actually present is difficult to determine but superficially it seems correct. The only positive fact that can be announced is that segregation does take place and that it is more complicated than this hasty survey would indicate.

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